4. Work Plan Rationale

4. WORK PLAN RATIONALE

This section evaluates and identifies the data needs for completing the RI pertaining to the OCVZ Operable Unit. It defines data needs and data quality objectives (DQOs) necessary for each medium in terms of site characterization, risk assessment, evaluation of alternatives, and engineering design. A description of tasks planned for the RI is provided in Section 5 of the work plan. Additional details will be provided in the sampling and analysis plan (SAP), that is attached to this work plan.

Although much data have been collected at the INEL as a whole, there has been limited synthesis and analysis of data pertaining specifically to site conditions at the SDA. Additional review and evaluation of all of the existing data are important elements of the Focused RI/FS.

4.1 Objectives of the RI/FS

The OCVZ Operable Unit is defined as VOC contamination in the media of concern. The vadose zone begins at the ground surface and extends to the top of the Snake River Aquifer. As a general rule for the purposes of investigation, the vadose zone operable unit is initially assumed to be 1000 feet beyond the boundaries of the SDA. The modeling for migration of VOCs includes the pits and trenches as the sources of release to the vadose zone. However, these pits and trenches are treated as separate operable units that are not to be included with potential remediation efforts for the vadose zone operable unit. The objectives of the OCVZ Focused RI/FS include:

- Determine the extent of the volatile organic contamination in the vadose zone beneath and adjacent to the SDA.

- Determine site-specific transport properties.

- Determine the current and future risk posed by VOCs to human health and the environment

- Conduct treatability studies to develop and evaluate candidate remediation technologies

- Develop the appropriate remedial alternative based on the nine CERCLA criteria.

A phased approach which includes a remedial investigation baseline risk assessment and feasibility study, vapor vacuum extraction (VVE) treatability study, to reach a proposed plan and record of decision will be used to meet these objectives.

To provide the basic data to meet the objectives of the OCVZ Focused RI/FS eleven specific tasks have been identified including:

1. **Soil Temperature and Vapor Concentration:** This activity will provide information on the temperature profile of the surficial sediments and measure organic vapors in the surficial sediments. Data will be used to determine the seasonal variations in vapor concentrations

and temperature and support the treatability study by giving information on concentrations of organic contaminants in the vapor phase and vapor phase transport mechanisms of VOCs in the surficial sediments. Those data would be used in determining short circuiting around the extraction well.

2. **Vapor Port Monitoring:** This activity will provide data to determine the vertical and horizontal concentration gradients of the VOC plumes and determine a baseline level of VOCs in the vadose zone. This monitoring will support the risk assessment, treatability study and remedial alternative evaluation. Modeling groundwater and to aid in the definition of the vertical and areal extent of the VOC plume in the vadose zone. The modeling will include interpolation of discreet data points, Henry's law estimations and two or three dimensional concentration profiles.

3. **Perched Water:** This study will develop a better understanding of the occurrence of perched water to determine if perched conditions are acting as a retardant for vapor transport. Perched water volume and migration will be assessed to determine the effect of aqueous transport on the VOC flux to the groundwater. Perched water monitoring will provide information on how perched water bodies control vertical permeability of the interbeds and horizontal and vertical soil gas movement. Concentrations of VOCs in perched water will be analyzed. Modeling will be used to estimate the relative contribution of perched water to the overall transport of VOCs in the subsurface.

4. **Vapor Port Permeability:** This parameter will be measured at selected port locations in the monitoring wells and will be used to help define the optimum zones of extraction for the treatability study. The permeability affects several objectives for the Focused RI/FS including definition of the radius of influence, number and location of wells, and the vertical zone for extraction. Modeling in the form of pressure and flow grids and two or three dimensional concentration profiles may be used to help meet these objectives.

5. **Basalt Tracer Studies:** This study will measure the horizontal and vertical diffusion in the basalt. The data will be used with the data from vapor port monitoring to calculated the VOC flux to groundwater which is expected to be the primary exposure pathway in the risk assessment. This data will yield more representative estimates for basalt porosity and permeability. To support treatability studies, those data will be used in the modeling of the concentration profiles and flow and pressure grids to support the estimation of the radius for influence, number and location of wells, and the vertical zone for extraction.

6. **Downhole Barometric Pressure/VOC Concentration:** This task will support the treatability study and provide information on the correlation and relationship of barometric pressure and VOC concentration. Those data will be used to bracket VOC concentration values in the plume due to barometric pressure variations.

7. **Meteorological Data:** This task will incorporate existing meteorological data from environmental monitoring stations at the RWMC to provide specific control information

for data collection supporting the treatability study and average values to support the air pathway calculations for the risk assessment.

8. **Stratigraphy and Structural Geology:** This activity is ongoing as a part of the existing data evaluation to gain a getter understanding of the subsurface stratigraphy and geology and the relationship of the subsurface to VOC migration in the vadose zone. Further logging procedures will be conducted with the installation of the six monitoring wells.

9. **Open Well Vapor Sampling:** This monitoring will provide information in determining the VOC concentrations in the vadose zoned above the 240 ft interbed. Open well data will be used to further define the extent and concentration of the VOC plume. This data will be used in mass balance, integration and concentration profile modeling which will help define the extent and concentration of the shallow portion of the plume which is currently believed to have the highest concentrations of VOCs.

10. **Groundwater Quality and Evaluation:** This activity will provide information on the concentrations of VOCs in the groundwater outside of the SDA. The data will be used in estimating the areal extent of the VOC plume and the flux of VOCs to the ground water. This data is especially important because no information can be gathered within the SDA below the 240 ft level. Several objectives have been established for groundwater studies for OCVZ including groundwater elevation and quality, aquifer parameters, vertical concentration gradient in groundwater, and VOC flux to groundwater.

11. **VVE Treatability Study:** This study will evaluate the effectiveness of the system as a remediation alternative for the VOCs in the vadose zone. The objectives of the study are to develop cleanup criteria, extraction efficiencies, radius of influence and preferred zone of extraction. Empirical data and modeling will be used to meet those objectives. The details of the treatability study will be presented in the VVE Treatability Study Work Plan.

   Three additional tasks (contingent) have been identified. The criteria for performing the three contingent tasks is based on an evaluation of the data from the first phase of the field investigation (tasks 1-10). If more data is needed to define the extent of the organic sources to support the BRA or the Treatability Study (task II), the three contingent tasks will be performed.

12. **Soil-gas survey (contingent):** The purpose of this survey will be to determine the identity, location, and relative concentration of selected chlorinated VOCs in the vadose zone within the SDA. Soil gas samples will be extracted from approximately 30 in. below the ground surface, collected in a Tedlar bag, and analyzed with a gas chromatograph. The survey will determine whether changes in organic vapor concentrations have occurred and further characterize the soil-gas distribution for the organic contamination in the vadose zone.

13. **VOC surface flux (contingent):** The VOC surface flux is important in projecting the time variations of the VOC plume in the vadose zone. The VOC flux across the soil surface

will be estimated using a flux chamber. The purpose of this study is to estimate the flux during typical soil conditions while simultaneously estimating or measuring soil moisture content, surface permeability, and soil temperature.

14. **Soil moisture (contingent):** The task objective is to obtain the soil moisture profile within surficial sediments from approximately 12 locations within the SDA. Data will be collected on the soil moisture profile on a periodic basis to determine the potential infiltration rates, distribution of moisture content, and effective soil porosity with the SDA.

As discussed in the following sections, a number of data gaps in the existing information about the organic contamination in the vadose zone have been identified. The need to fill a data gap and the degree to which it is filled are prioritized to most efficiently meet the objectives of the Focused RI/FS as stated above. Ultimately the Focused RI/FS will provide the information necessary to establish potential risks to human health and the environment, as well as to select the most technically viable and cost-effective remedial alternative for the site. The decision framework for developing the remedial investigation to support these objectives can be summarized as follows:

1. What VOC contaminants are present?

2. What are the concentrations of these VOC contaminants in the environment?

3. What is the vertical and horizontal extent of the VOC contamination?

4. What is the potential for the contaminants to move within the environment?

5. What is the flux of VOCs to the atmosphere and the groundwater?

6. What are the risks posed to humans and the environment by these VOC contaminants now and in the future?

7. When is the risk a maximum?

8. If the risks from the contaminants are unacceptable, how can the risks be reduced to acceptable levels?

9. What specific technologies can be utilized?

10. If the risks can be reduced, what is the most cost-effective way to reduce the risks?

The activities that provide answers to the first five questions above are classified as site characterization activities and will be conducted during the OCVZ RI and the Groundwater OU Track II. A risk assessment will be performed to answer questions 7, 8, and 9. The FS and VVE treatability study will provide the answers for questions 6, 9, 10, and 11.

4.2 Data Use Requirements and Data Quality Objectives

The development of DQOs governing proposed sampling activities for the OCVZ Operable Unit constitutes an integral part of the RI/FS program. The DQOs are developed through an iterative process establishing the data required for the evaluation of remedial alternatives. DQOs are incorporated as parts of SAPs, quality assurance project plans (QAPPs), and work plans applied to site investigations.

4.2.1 Data Users

Data users can be subdivided into two general categories—primary and secondary users. Primary users, are those organizations and individuals who are directly involved in Focused RI/FS activities. Secondary data users are those individuals or organizations who use outputs from the RI/FS studies to support their activities. Secondary users include personnel directing other projects at the site, facility personnel, environmental impact personnel, etc.

Most data needs are defined by primary users. Secondary users may provide input to the decision makers and primary users by communicating generic or site-specific needs or regulatory requirements or by comment or question during the review process.

4.2.2 Evaluation of Available Information

Available information is reviewed and evaluated in the scoping phase of the RI/FS process. This review provides the foundation for additional onsite activities and serves as the data base for RI/FS scoping. A review and evaluation of available information is presented in Sections 2 and 3 of this work plan. Existing data will be validated, where possible, according to EPA guidelines and protocols. This process will enable data to be placed in specific use categories such as screening level, presence or absence of contaminants, engineering, design, and legally valid and enforceable data.

4.2.3 Conceptual Site Model

During the tri-agency scoping meeting (September 12 and 13, 1991, Idaho Falls, Idaho) a conceptual site model (CSM) of the OCVZ Operable Unit was developed (see Section 3). In addition to the groundwater pathway to receptors, air and soil pathways were identified. Data requirements for quantifying transport via the three pathways were defined, existing data sets were reviewed, and data needs were identified.

4.2.4 Data Uses

Data uses during the RI/FS fall into the following general purpose categories.

- *Site Characterization.* Data will be acquired to supplement existing information so the extent of VOC contamination in the vadose zone beneath and adjacent to the SDA can be better defined. This information will be used to calibrate computer modeling activities which will be used to predict and estimate the extent of the vadose zone.

- *Modeling.* Empirical data collected during the remedial investigation and VVE treatability study will be expanded through modeling to answer specific objectives of the Focused RI/FS. The basic approach is to employ simple modeling strategies based on available data and to perform sensitivity analyses to obtain a qualitative (and quantitative where possible) understanding of the Focused RI/FS objectives. The specific modeling approach will be tailored to each objective and will utilize several approaches including mass balances, integration or interpolation from discrete data points, one, two, or three dimensional concentration profiles, pressure and flow nets, and Henry's law estimations. The modeling will be done in a phased approach; striving for an initial qualitative understanding of the situation which will be followed by a more quantitative analysis, if the available data and end use of the information warrant it.

- *Risk Assessment.* Data will be acquired to evaluate the threat posed by the VOC contamination in the vadose zone beneath and adjacent to the SDA to human health and the environment. Risk assessment data needs include sufficient modelling data to adequately evaluate the threat to public health and welfare through exposure to various media. Data of sufficient quality and quantity will be acquired through field sampling activities and related modeling to resolve baseline risk assessment issues including VOC transport to the groundwater and atmosphere.

- *Evaluation of Remedial Action Alternatives.* Data collected to support evaluation of various remedial technologies include site characteristics and engineering information required for initial screening of alternatives, feasibility-level design, and preliminary cost estimates, as well as data required to support performance assessment. Information collected include physical, chemical, or hydrogeologic data that will be obtained by various laboratory and field means.

- *Engineering Design of Alternatives.* Data collected during the RI/FS can be used to develop a preliminary data base for engineering design purposes. Data may need to be collected to support design of selected remedial alternatives to be implemented at a later time [after the signing of the record of decision (ROD)]. As in the case of the evaluation of remedial action alternatives, data may include physical, chemical, and hydrogeological information. The data may be obtained by both laboratory and field activities and will be extended by modeling as necessary.

- *Worker Health and Safety.* Data are required to establish the level of protection needed for RI/FS investigators. Data collection will focus on exposure levels for contaminants of concern.

4.2.5 Data Types

The data use categories just described define the general purpose and intent for collecting additional data. Based on the intended uses, a list of target analytes for soil and groundwater sampling activities include chloroform, 1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, trichloroethylene, and tetrachloroethylene. Numerous previous investigations

have analyzed soil gas, subsurface soils, borehole vapors, and groundwater for the entire suite of volatile organic target compounds, including degradation products such as vinyl chloride. These previous investigation have not detected significant quantities of degradation products in either the air, soil, or water media, with the exception of chloroform and to a lesser degree, methylene chloride which have been detected in the subsurface vapor plume. Nevertheless, the planned perched water and current aquifer monitoring for volatile organic compounds include analysis for typical degradation products. To date, these compounds have not been detected. Off-site confirmation analysis of split vapor samples will provide not only a check of the quantitative accuracy of the portable GC measurements, by also permit further qualitative confirmation of the exact volatile organic species, including degradation products, present in the vadose zone. The target analytes include known and suspected degradation products and all VOCs found in the Snake River Plains Aquifer (SRPA) that exceeded Federal drinking water standards or goals or ambient water quality criteria. The data types to be collected during the RI and the corresponding DQOs are identified in Table 4-1. Also provided in Table 4-1 are methods of data determination, the intended data uses and the analytical levels appropriate to the data uses.

The data types presented in Table 4-1 have been identified on the basis of site characterization needs and on the basis of the preliminary remedial alternatives identified for the site (see Section 3). Candidate remedial alternatives identified in Section 3 for the OCVZ included VVE. The proposed data types for characterization of the organic contamination in the vadose zone presented in Table 4-1 include those that will be required to properly evaluate the VVE and other suggested remedial alternatives. A no action alternative will also be considered and will be evaluated with the aid of modeling studies.

Important data types for the OCVZ have been identified as stratigraphy and structural geology, VOC flux to the atmosphere and groundwater, perched and groundwater quality, basalt permeability, vapor monitoring, and VOC vapor concentrations gradients.

Important data types for the groundwater (saturated zone) have been identified as aquifer transport parameters, vertical VOC concentration gradients, groundwater quality and elevations, and VOC flux to groundwater.

Sample collection procedures and critical sample specifications are discussed in the field sampling plan (FSP) accompanying this work plan in the SAP (Attachment III).

4.2.6 Data Quality Needs

The various tasks and phases of a remedial investigation typically require different levels of data quality. Important factors in defining data quality include selecting appropriate analytical levels and identifying contaminant levels of concern. In general, increasing accuracy and precision are obtained with increasing cost and time. Individual DQOs and the appropriate analytical levels associated with each data need are given in Table 4-1.

Table 4-1. Data quality objectives summary.

Task (measurement)	Method	Analytical level	Data Validation level	Data uses	Precision	Accuracy	Detection limit	Critical Samples
1. Vapor Concentration/Soil Temperature[12]								
VOCs[9]	Portable GC (O&MM 9.8)	II	C	N&E, RA	± 10%	± 20%[1]	1 ppm (CCl$_4$)	None
	5% offsite via mod. EPA TO-14 or Mod. SW 846 method 8240/8260	V	A	M&E, RA	per lab SOW	per lab SOW	<500 ppb (CCl$_4$)	
Temperature	Sensor/data log	II	C	RA	± 2°C	± 2°C[2]	Not applicable (NA)	None
2. Vapor Port Monitoring[12]								
VOCs[9]	Portable GC (O&MM 9.8)	II	C	N&E, RA	± 10%	± 20%[1]	1 ppm (CCl$_4$)	1 from each
	5% off site via mod. EPA TO-14 or Mod. SW 846 method 8240/8260	V	A	N&E, RA	per lab SOW	per lab SOW	<500 ppb (CCl$_4$)	of 6 wells
3. Perched Water[13]								
Water level	Electronic Sensor	II	C	N&E, RA	NA	± 0.1 ft[2]	0.01 ft	
Temperature	Hydrolab	II	C	N&E, RA	NA	± 0.15°C[2]	0.01°C	
Conductivity	Hydrolab	II	C	N&E, RA	NA	± 1% of range[2]	4 digits	
pH	Hydrolab	II	C	N&E, RA	NA	±0.1 pH unit[2]	0.01 units	
VOCs[8]	CLP Organics SOW (Cur. Rev.)	IV	A	N&E, RA	Per SOW	Per SOW	Per CLP SOW[3]	1 total
Metals[10]	CLP Inorganics SOW (Cur. Rev.)	III	A	N&E, RA	Per CLP SOW	Per CLP SOW	Per CLP SOW[5]	
Radionuclides[11]	Gamma spectrometric analysis RML	IV	C	N&E, RA	Per RML SOPs	Per RML SOP	Per RML SOP[4]	
Anions	EPA 300.0	III	C	N&E, RA	Per SOW	Per SOW	Per SOP	
Semi-Volatiles	CLP organics SOW (Cur. Rev.)							
Gross alpha/beta[11]	ERD SOW	IV	A	N&E, RA	Per RML SOPs	Per RML SOP	Per RML SOW[4]	
Isotopic specific[11]	ERD SOW							
4. Vapor Port Permeability[12]								
Vapor port pressure	Pressure transducer, DAS, flowmeter	II	C	RA	± 5 psi	± 1 psi[2]		None
		II	C	RA	± 20%	± 20%[2]		

Table 4-1. (continued).

Task (measurement)	Method	Analytical level	Data Validation level	Data uses	Precision	Accuracy	Detection limit	Critical Samples
1. Vapor Concentration/Soil Temperature[12]								
VOCs[9]	Portable GC (O&MM 9.8)	II	C	N&E, RA	± 10%	± 20%[1]	1 ppm (CCL$_4$)	None
	5% offsite via mod. EPA TO-14 or Mod. SW 846 method 8240/8260	V	A	M&E, RA	per lab SOW	per lab SOW	<500 ppb (CCl$_4$)	
Temperature	Sensor/data log	II	C	RA	± 2°C	± 2°C[2]	Not applicable (NA)	None
5. Basalt Tracer Studies[12]								
Tracer concentration	Portable GC (O&MM 9.8)	II	C	RA	± 10%	± 20%[1]	1 ppm (SF$_6$)	None
Elapsed time								
Temperature	DAS Sensor	II	C	RA	± 1°C	± 1°C[4]	NA	
6. Downhole Barometric Pressure/VOC Concentration[12]								
Pressure	Pressure transducer	II	C	N&E, RA	± 10%	± 20%	N/A	1 from each well
VOCs[9]	Portable GC (O&MM 9.8)	II	C	N&E, RA	± 10%	± 20%	1 ppm (CCl$_4$)	
	5% offsite via Mod. EPA TO-14 or Mod. SW 846 method 8240/8260	V	A	N&E, RA	Per lab SOW	Per lab SOW	<500 ppb (CCl$_4$)	
7. Meteorological Data								
Wind speed	Anemometer	II	C	APA,RA	NA	NA	0.1 mph	NA
Direction	Vane	II	C	APA,RA	NA	NA	1°	
Barometric Pressure	Barometer	II	C	APA,RA	± 1 torr	± 1 torr	1 torr	
Temperature	Sensor	II	C	APA,RA	± 1°F	± 1°F	0.1°	
8. Stratigraphy and Structural Geology	Data survey	NA		NA	NA	NA	NA	NA

Table 4-1. (continued).

Task (measurement)	Method	Analytical level	Data Validation level	Data uses	Precision	Accuracy	Detection limit	Critical Samples
1. Vapor Concentration/Soil Temperature[12]								
VOCs[9]	Portable GC (O&MM 9.8) 5% offsite via mod. EPA TO-14 or Mod. SW 846 method 8240/8260	II V	C A	N&E, RA M&E, RA	± 10% per lab SOW	± 20%[1] per lab SOW	1 ppm (CCL$_4$) <500 ppb (CCL$_4$)	None
Temperature	Sensor/data log	II	C	RA	± 2°C	± 2°C[2]	Not applicable (NA)	None
9. Open Well Vapor Sampling[12] **a.Well Gas Sampling[12]**								
VOCs[9]	Portable GC (O&MM 9.8) 5% offsite via Mod. EPA TO-14 or Mod. SW 846 method 8240/8260	II V	C A	N&E, RA N&E, RA	±10% Per lab SOW	±20%[1] Per lab SOW	1 ppm (CCL$_4$) <500 ppb (CCL$_4$)	1 from each well
b.Shallow Well Screening[12]								
VOCs[9]	Portable GC (O&MM 9.8)	II	C	N&E, RA	±10%	±20%	1 ppp (CCL$_4$)	1 from each well
10. Groundwater Quality and Elevation[13]	Groundwater OU 7-06 evaluation of data	NA		NA	NA	NA	NA	GW-SAP
11. Treatability Study[12]								
VOCs[9]	Portable GC (O&MM 9.8)	II	C	RD	± 10%	± 20%	1 ppm (CCL$_4$)	TS Work Plan

Table 4-1. (continued).

Task (measurement)	Method	Analytical level	Data Validation level	Data uses	Precision	Accuracy	Detection limit	Critical Samples
1. Vapor Concentration/Soil Temperature[12]								
VOCs[9]	Portable GC (O&MM 9.8)	II	C	N&E, RA	± 10%	± 20%[1]	1 ppm (CCL$_4$)	None
	5% offsite via mod. EPA TO-14 or Mod. SW 846 method 8240/8260	V	A	M&E, RA	per lab SOW	per lab SOW	<500 ppb (CCl$_4$)	
Temperature	Sensor/data log	II	C	RA	± 2°C	± 2°C[2]	Not applicable (NA)	None
12. Soil-Gas Survey (Contingent)[12]								
VOCs[9]	Vapor Probe sampler Portable GC (O&MM 9.8)	II	C	APA,N&E,S TM	± 10%	± 20%	1 ppm (CCL$_4$)	TBS if completed
13. VOC Surface Flux (Flux Chamber) (Contingent)[12]								
VOCs[9]	Flux chamber (EPA/600/8-86/008)	II	C	APA	± 10%	± 20%[1]	1 ppm (CCL$_4$)	TBS if completed
Sweep air flow rate	Portable GC (O&MM 9.8) Flowmeter	II	C	APA	± 20%	± 20%[2]	0.5 L/minute	
Meteorological data	NOAA, USGS, EG&G	II	C	APA	See Sec. 2.5.2.13	See Section 2.5.2.13	See Section 2.5.2.13	N/A
Vapor temperature	K-type thermocouple	II	C	APA	± 1°C	± 1°C[2]	0.5°C	
Surface permeability	Permeameter/flowmeter	NA		TM	± 20%	NA	NA	
Emission rate	Calculated	II	C	APA	± 10%	± 50% (per EPA)	1 μg/min•m^2	

Table 4-1. (continued).

Task (measurement)	Method	Analytical level	Data Validation level	Data uses	Precision	Accuracy	Detection limit	Critical Samples
1. Vapor Concentration/Soil Temperature[12]								
VOCs[9]	Portable GC (O&MM 9.8)	II	C	N&E, RA	± 10%	± 20%[1]	1 ppm (CCL_4)	None
	5% offsite via mod. EPA TO-14 or Mod. SW 846 method 8240/8260	V	A	M&E, RA	per lab SOW	per lab SOW	<500 ppb (CCl_4)	
Temperature	Sensor/data log	II	C	RA	± 2°C	± 2°C[2]	Not applicable (NA)	None
14. Soil Moisture (Contingent)	Field soil moisture meter	NA		TM	± 1% volume	± 2% by volume	2% moisture content	TBS if completed

APA - air pathway analysis
N&E - nature and extent of contamination
TBS - To be specified
GW - Groundwater
NA - not applicable
RA - risk assessment
RD - remedial design

1. Percent of known reference value
2. Variation from calibration value
3. CLP SOW for Organics - (current revision) (Appendix N)
4. EG&G-ID Internal Technical Report ST-CS-DV3-89, May 1989 (Appendix O)
5. CLP SOW for Inorganics - 2/89, 6/89 (current revision) (Appendix N)
6. Data Quality Objectives for Remedial Response Activities Development Process, NTIS PB88-131370
7. SOPs for Data Validation (Appendix O)
8. Refer to Table 4-3 for target analyte list of volatile organic compounds for water samples
9. Refer to Table 4-2 for target analyte list of volatile organic compounds for verification gas samples
10. Refer to Table 4-4 for target and analyte list of organic compounds for water samples
11. Refer to Table 4-5 and 4-6 for target analyte lists of radionuclides for water samples
12. Medium is gas
13. Medium is water

Table 4-2. Target analyte list and detection limits for soil gas verification samples.

Volatiles	Detection Limit [a] (ppmv)	MDL (ng)
1. Acetone	25	150[b]
2. Benzene	1	8
3. Bromoform	1	8
4. 2-Butanone	25	150[b]
5. Chloroform	1	8
6. Carbon Tetrachloride	1	8
7. Chlorobenzene	1	8
8. 1,1-Dichloroethane	1	8
9. 1,2-Dichloroethane	1	8
10. 1,1-Dichloroethene	1	8
11. Ethylbenzene	1	8
12. Methylene Chloride	1	8
13. 4-Methyl-2-pentanone	25	150[b]
14. 1,1,2,2-Tetrachloroethane	1	8
15. Tetrachloroethene	1	8
16. Toluene	1	8
17. 1,1,1-Trichloroethane	1	8
18. Trichloroethene	1	8
19. 1,1,2-Trichlorotrifluoroethane	1	8
20. Xylene (meta & para)	1	8
21. Xylene (ortho)	1	8

a = The PRQL levels assume that 10 mls is delivered to the analytical system.

b = Estimate, to be determined

Table 4-3. Target analyte list and detection limits for volatile organic compounds in water samples.

Compound	CAS Number	Detection Limits[1] Water ug/L	On Column (ng)
1. Chloromethane	74-87-3	10	(50)
2. Bromomethane	74-83-9	10	(50)
3. Vinyl Chloride	75-01-4	10	(50)
4. Chloroethane	75-00-3	10	(50)
5. Methylene Chloride	75-09-2	10	(50)
6. Acetone	67-64-1	10	(50)
7. Carbon Disulfide	75-15-0	10	(50)
8. 1,1-Dichloroethene	75-35-4	10	(50)
9. 1,1-Dichloroethane	75-34-3	10	(50)
10. 1,2-Dichloroethene	540-59-0	10	(50)
11. Chloroform	67-66-3	10	(50)
12. 1,2-Dichloroethane	107-06-2	10	(50)
13. 2-Butanone	78-93-3	10	(50)
14. 1,1,1-Trichloroethane	71-55-6	10	(50)
15. Carbon Tetrachloride	56-23-5	10	(50)
16. Bromodichloromethane	75-27-4	10	(50)
17. 1,2-Dichloropropane	78-87-5	10	(50)
18. cis-1,3-Dichloropropene	10061-01-5	10	(50)
19. Trichloroethene	79-01-6	10	(50)
20. Dibromochloromethane	124-48-1	10	(50)
21. 1,1,2-Trichloroethene	79-00-5	10	(50)
22. Benzene	71-43-2	10	(50)
23. trans-1,3-Dichloropropene	10061-02-6	10	(50)
24. Bromoform	75-25-2	10	(50)
25. 4-Methyl-2-pentanone	108-10-1	10	(50)
26. 2-Hexanone	591-78-6	10	(50)
27. Tetrachloroethene	127-18-4	10	(50)
28. Toluene	108-88-3	10	(50)
29. 1,1,2,2-Tetrachloroethane	79-34-5	10	(50)
30. Chlorobenzene	108-90-7	10	(50)
31. Ethyl Benzene	100-41-4	10	(50)
32. Styrene	100-42-5	10	(50)
33. Xylenes (Total)	1330-20-7	10	(50)

1. Quantitative limits (CQR - contract required quantitative limits) are matrix dependent.

Table 4-4. Target analyte list and detection limits for inorganics for water samples.

CAS #	Compound	Detection Limits[a] Water (ug/1)
7429-90-5	Aluminum	200
7440-36-0	Antimony	60
7440-38-2	Arsenic	10
7440-39-3	Barium	200
7440-41-7	Beryllium	5
7440-43-9	Cadmium	5
7440-70-2	Calcium	5000
7440-47-3	Chromium	10
7440-48-4	Cobalt	50
7440-50-8	Copper	25
7439-89-6	Iron	100
7439-92-1	Lead	5000
7439-95-4	Magnesium	15
7439-96-5	Manganese	0.2
7439-97-6	Mercury	40
7440-02-0	Nickel	5000
7440-09-7	Potassium	5
7782-49-2	Selenium	10
7440-22-4	Silver	5000
7440-23-5	Sodium	10
7440-28-0	Thallium	50
7440-66-6	Zinc	20

a. Specific quantitation limits are highly matrix dependent. The quantitation limits listed herein are provided for guidance and may not always be achievable.

Table 4-5. Target analyte list and detection limits by gamma spectrometry for environmental 540 ml water samples.[a,b]

Radionuclide	pCi/ml	Radionuclide	pCi/ml
Na-22	1.0E-2	Ce-144	7E-2
Al-26	1.0E-2	Eu-152	3E-2
K-40	2E-1	Eu-154	4E-2
Sc-46	2E-2	Eu-155	4E-2
Cr-51	8E-2	Hf-181	2E-2
Mn-54	1.0E-2	Ta-182	5E-2
Co-58	1.0E-2	Hg-203	1.0E-2
Fe-59	2E-2	ThTl-232	1.6E-1
Co-60	2E-2	ThPb-232	4E-2
Nn-65	3E-2	ThBi-232	2E-1
Nb-94	1.0E-2	ThRa-232	4E-1
Zr-95	2E-2	ThAc-232	8E-2
Nb-95	1.0E-2	Ra-226	2E-1
Ru-103	1.0E-2	RaPb-226	2E-1
RuRh-106	1.0E-1	RaBi-226	2E-1
Agm-108	1.0E-2	U-232	1.1E+1
Agm-110	1.0E-2	U-234	4.3E+1
Sb-124	1.0E-2	Th-234	5E-1
Sb-125	4E-2	Pa-234	2.3E+0
Cs-134	1.0E-2	U-235	7E-2
Cs-137	3E-2	Pu-239	1.0E+2
		Am-241	5E-2

```
                    Sample Description

Matrix:      Water     Geometry:  540 ml poly
Volume:      540 ml               bottle
Count Time:  16 hours   Mass:     N/A
```

NOTE 1   The detection limits for given radionuclides will vary from sample to sample due to the radionuclide mixture and concentrations in the sample. Other parameters affecting the detection limits can be the sample matrix, sample geometry, counting times and the detector system used.

NOTE 2   The detection limits for the Radon/Thoron daughters were determined at or near equilibrium and should only be applied under these conditions.

a. Reference: Radiation Measurements Laboratory

b. If a smaller sample is analyzed the detection limits may be higher.

Table 4-6. Target analyte list and detection limits for isotope specific alpha spectrometry.

Element	Isotope	Detection Limit
Plutonium	$Pu^{238}, Pu^{239/240}$	0.2 pCi/l
Uranium	$U^{234,235,238}$	0.5 pCi/l
Americium	Am^{241}	0.2 pCi/l

a. Based on 100 mls of water sample. If a smaller volume is analyzed the detection limits may be higher.

b. Isotope specific analysis will be done if gross alpha/beta analysis of sample reflects > 10 pCi/l.

c. Reference: ERD SMO SOW-33

Table 4-7. Risk based detection limits.

Analyte	Medium	Risk-Based Detection Limit	Practical Quantitation Limits
CCl$_4$	Air	3 mg/m^{3a}	3.15 mg/m^{3c}
	Water (perched/aquifer)	0.3 μg/l^b	
	Soil	5 mg/kg^b	
TCE	Air	27 mg/m^{3a}	5.36 mg/m^{3c}
	Water (perched/aquifer)	3 μg/l^b	
	Soil	60 mg/kg^b	
Chloroform	Air	5 mg/m^{3a}	4.87 mg/m^{3c}
	Soil	100 mg/kg^b	
	Water (perched/aquifer)	0.3 μg/l^b	
Tetrachloroethylene	Air	34 mg/m^{3a}	6.7 mg/m^{3c}
	Water (perched/aquifer)	1 μg/l^b	
	Soil	10 mg/kg^b	
1,1-Dichloroethylene	Air	2 mg/m^{3a}	3.96 mg/m^{3c}
	Water (perched/aquifer)	.07 μg/l^b	
	Soil	1 mg/kg^b	
1,1,2,2-Tetrachloroethane	Air	0.7 mg/m^{3a}	6.93 mg/m^{3c}
	Water (perched/aquifer)	.09 μg/l^b	
	Soil	3 mg/kg^b	
1,2-Dichloropropane	Air	35 mg/m^{3a}	4.48 mg/m^{3c}
	Water (perched/aquifer)	1 μg/l^b	
	Soil	9 mg/kg^b	

a. 10% of TLV-TWA (Threshold Limit Values - time weighted average), *Threshold Limit Values and Biological Exposure Studies for 1988-1989*, American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1988.

b. EPA Region 10 "Supplemental Risk Assessment Guidance for Superfund," August 16, 1991.

c. Based on the injection of 10 ml samples during analysis.

To identify appropriate data needs, preliminary applicable or relevant and appropriate requirements (ARARs) are identified. Because of the iterative nature of the RI/FS process, ARARs identification continues throughout the RI/FS as a better understanding is gained of site conditions, site contaminants, and remedial action alternatives.

During RI/FS planning, an identification of chemical, location, and action-specific ARARs is made to develop cleanup objectives and focus the collection of data. Chemical-specific ARARs are expressed as numerical values and are either derived from specific standards [i.e., maximum contaminant levels (MCLs) as specified in the Safe Drinking Water Act] or are health based. By identifying these standards early in the planning, appropriate analytical methods and detection limits can be selected for the contaminants of concern. The analytical methods proposed in Table 4-1 were selected based on the chemical-specific requirements identified in the preliminary ARARs analysis.

In addition, location-specific ARARS need to be determined during RI/FS planning to ensure impacts to identified historic or archeological resources are minimized during field investigations. Since all RI activities are within the SDA, no historical or archeological resources will be impacted. Action-specific ARARS will also be identified to determine if certain actions trigger regulatory requirements.

4.2.7 Data Quantity Needs

The number of samples that need to be collected during an RI/FS can be determined by using several approaches. In instances where data are lacking or are limited, a phased sampling approach may be useful. In the absence of available data, an approach or rationale will need to be developed to justify the sampling locations selected. In situations where data are available, statistical techniques may be useful in determining the number of additional data required. These approaches have been used to determine the data quantity needs for the RI. Section 5 of the work plan and the FSP provide the supporting rationale for the quantity of data to be collected.

4.2.8 Precision, Accuracy, Representativeness, Completeness, and Comparability Parameters

The precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters are indicators of data quality. Ideally, the end use of the data collected should define the necessary PARCC parameters. Once the PARCC requirements have been identified, appropriate analytical methods can be chosen to meet the goals and requirements established. A complete discussion of the PARCC requirements for the RI are discussed in the quality assurance project plan.

4.2.9 Data Collection Program

A data collection program has been developed as a part of the DQO process. The rationale to support the collection of additional data for the RI is provided in Table 4-1. The following sections provide additional details to support the information provided in the tables. These sections summarize known information about each medium and identify data needs and DQOs. These data needs were developed to test the conceptual site model (CSM) presented in Section 3.

DOE has made it a policy to limit drilling, which might result in an open pathway for contaminant transport through the 240-ft interbed within the boundaries of the SDA. Hence, no drilling through the 240-ft interbed within the SDA is planned in this work plan, even though vapor ports under the center of the VOC vapor plume and below the 240-ft interbed would be helpful in determining the flux to the groundwater.

4.3 Specific Data Gaps

The identification of data needs is the most important part of the scoping process. These data needs were identified by evaluating the existing data and determining what additional data were necessary to characterize the site, develop a better conceptual understanding of the site and its inherent risks, better define the ARARs, and identify and screen remedial alternatives.

During the tri-agency scoping meeting (September 12 and 13, 1991, Idaho Falls, Idaho) a CSM of the OCVZ Operable Unit was developed. In addition to the groundwater pathway to receptors, air and soil pathways were identified. Data requirements for quantifying transport via the three pathways were defined and existing data sets were reviewed. During a meeting on March 12, 1992 the scope of the RI/FS was focussed to emphasize on the Treatability Study and modeling.

4.3.1 Source Term Characterization

This section identifies source term characterization data requirements that should be addressed in the RI/FS program for the organic contamination in the vadose zone beneath the SDA. A proposed list of target analytes for air, soil, and groundwater sampling activities, together with their corresponding proposed detection limits is presented in Table 4-1. Information presented on sources of volatile organic contamination (Section 3.2) were evaluated to identify data gaps that should be filled as part of the focussed RI/FS investigation. In addition, data from Groundwater Track II (OU 7-06) will be used to the fullest extent possible to avoid duplication of effort.

4.3.1.1 Primary Source (Pits). The primary source of VOCs in the SDA are buried drums containing sludges. Drums received during and after 1970 were not buried, but they were stored at the Transuranic Storage Area (TSA) adjacent to the SDA. Estimated volumes of VOCs contained in those buried drums were 24,400 gal of CCl_4 and 25,000 gal of trichloroethylene, trichloroethane, tetrachloroethylene, and other chlorinated hydrocarbons, and 35,000 gal of Texaco Regal oil. Those drums were buried in Pits 2, 4, 5, 6, 9, and 10.

A projected exponential failure rate of the buried drums was supported by limited sampling results during drum retrieval at the SDA (McKinley and McKinney, 1980) and (Bishoff and Hudson, 1979). The estimated drum failure rate and the estimated vapor loss from the failed drum results in the VOC source to the vadose zone. The failure of a drum cannot be assumed to result in the complete and immediate release of the VOCs it contains for several reasons:

1. Failure of a drum is defined as a breach in the wall of the drum and may be no more than a small hole as opposed to catastrophic failure.

2. Some of the drums had plastic liners which would not necessarily fail when a drum failed.

3. Most of the VOCs placed in drums were mixed with an absorbent and had a thick sludge-like consistency. The mixture would not readily flow and the VOCs would have to desorb from the adsorbent.

A modeling and sensitivity analysis will be done to determine the distribution of the VOCs among the drums, vadose zone, and atmosphere.

Specific data needs for further source term characterization are:

*   Estimate how much of each VOC is present in the SDA today and the amount predicted to escape monthly/yearly in the future. This prediction should also indicate the pathway(s) for release of each constituent.

*   Estimate the sensitivity of the release rate to the amount of VOCs remaining in the buried drums.

4.3.1.2 Secondary Source (VOC Plume). The secondary source of VOCs is the vapor plume in the surficial soil, basalts, and interbeds beneath the SDA. The waste contained in the pits and trenches are outside the scope of the OCVZ Operable Unit and will be evaluated in another operable unit. The VOC plume in the vadose zone will be used as the effective contaminant source in generating the vertical concentration gradient and flux to the groundwater and atmosphere; however, preliminary modeling and empirical data (Walton et al. 1989) indicate that the rate of VOC release from the drums has decreased substantially. Walton et al. (1989) modeled the release and migration of chlorinated solvents from disposal pits at the SDA using a two-dimensional radial model with all source inventories lumped together into an equivalent disk source at the center. In an effort to improve the early model projections by Walton et al., the model has been extended to three dimensions so known sources could be separated into locations corresponding to the disposal pits to better define and delineate the plume. The general modeling approach and equations used are discussed in Section 4.3.5 and more completely in Walton et al. (1989). An areal projection of the VOC plume as estimated by recent computer modeling is shown in Figure 4-1. A cross-section projection is shown in Figure 4-2.

4.3.2 Air

The OCVZ CSM indicates that inhalation is an exposure pathway for VOCs. This pathway will be evaluated in the human health risk assessment using past soil-gas data collected at the RWMC and air quality data collected at the RWMC (SDA). Specific data needs for evaluation of the air pathway for the risk assessment are:

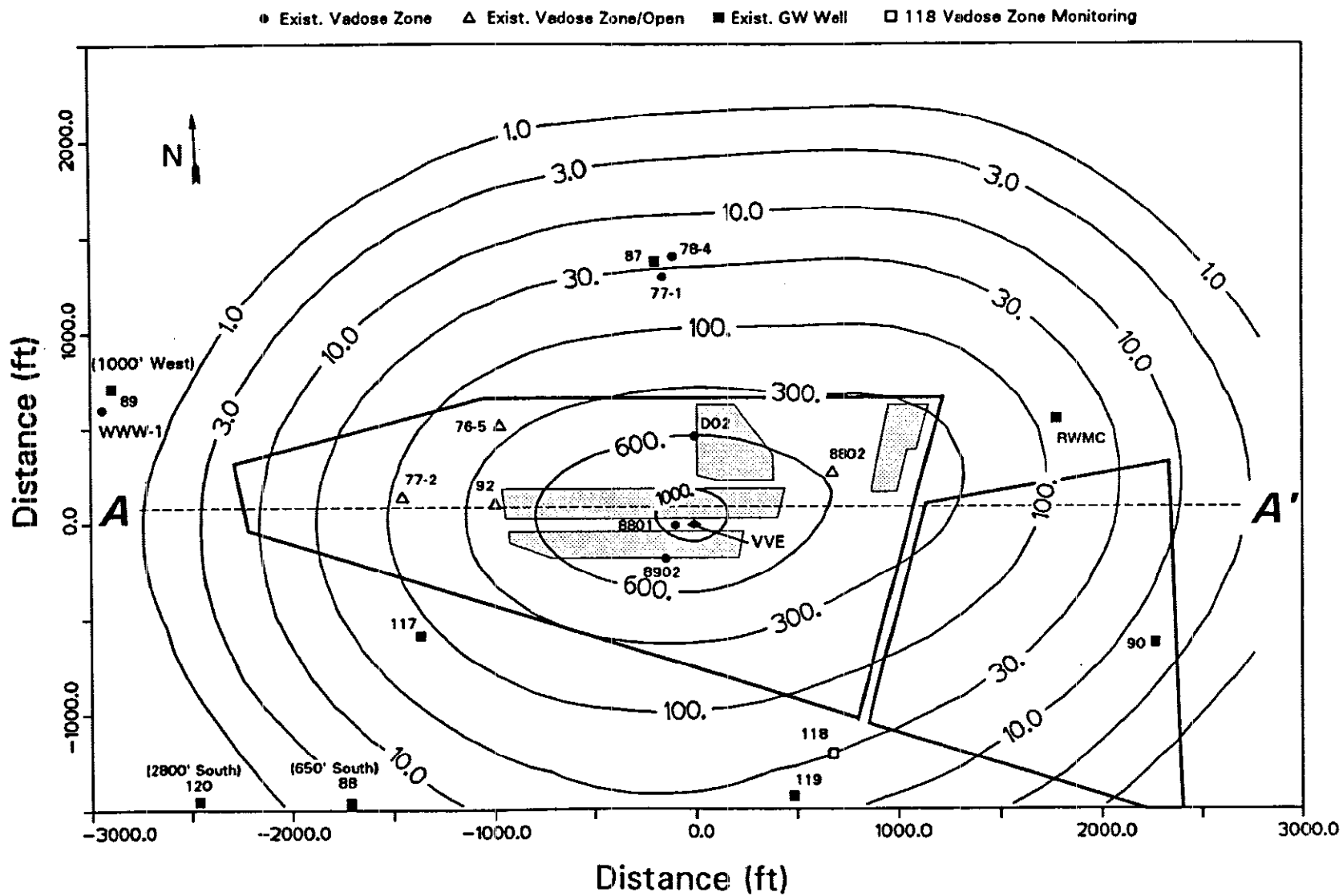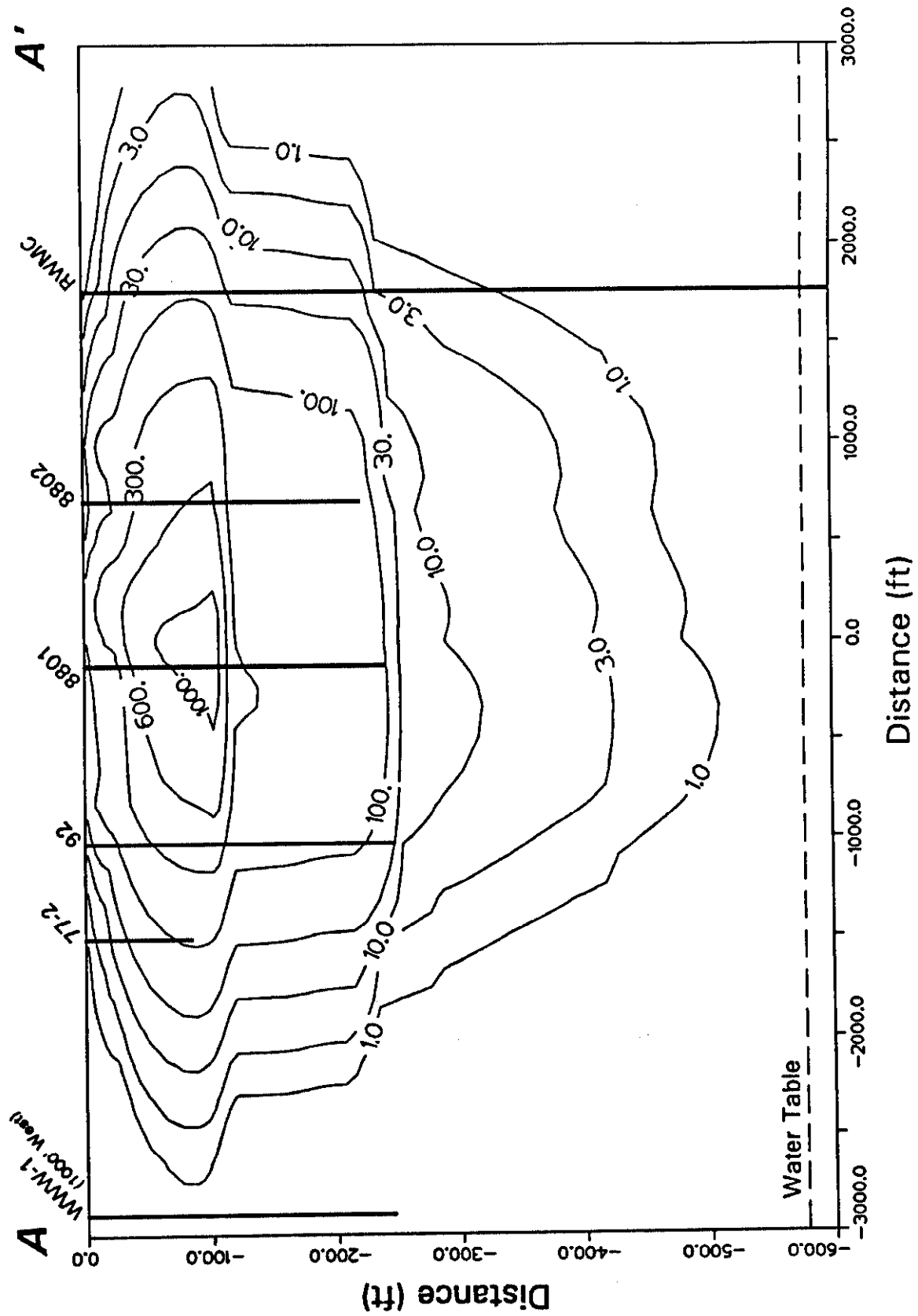*   Vertical concentration gradients of VOCs in surficial sediments.

Figure 4-1. Simulated carbon tetrachloride concentrations (ppm) at approximately 75-ft depth.

Figure 4-2. Simulated carbon tetrachloride concentrations (ppm) cross section A-A' looking north.

- Flux of VOCs to atmosphere.

An evaluation of the transport of the volatile organic contaminants requires a program that measures or estimates the flux of VOC contaminants across the soil surface to the atmosphere. A transport evaluation involves quantifying the VOC mass transported, and identifying the major sources of the VOC mass. Contaminant determination requires an understanding of emissions from the site and the dispersion and transportation mechanism in the atmosphere. A data collection program that meets the objectives stated above must address the air and soil dispersion characteristics of the SDA. This section describes potential sources and dispersion mechanisms at the SDA and the air data collection program requirements.

The SDA facility consists of disposal pits where drums containing VOCs have been buried. Hence, these pits are potential sources of volatile organic emissions to the atmosphere. The disposal pits at the SDA are man-made pits that have been filled with waste and covered with 3 to 10 ft of soil (RFI 1989). Gases may be emitted from the waste in the pits by diffusion through the soil overburden and through monitoring wells that surround the pits. The emissions from the disposal pits are likely to be controlled by the temperature of the waste, the thickness of the soil cover, the soil cover porosity, permeability, and contaminant concentrations in the waste.

Grab samples of ambient air have been analyzed for VOCs. These grab samples have shown VOCs, but not of a level to cause concern to the workers on the site. Air dosimeters have been worn by workers drilling wells into the SDA where VOCs are suspected. The results from these dosimeters also have not resulted in health concerns from VOCs for the workers.

All gaseous emissions from the SDA are dispersed and transported by various atmospheric processes. Atmospheric dispersion is determined by the meteorological conditions, the location and concentration of VOC flux across the soil surface, and the local terrain. Most emissions from the SDA can be characterized as fugitive emissions at ground level and at ambient temperature. Since the terrain around the site is flat, terrain effects should be negligible.

The meteorological conditions are continually changing, thus changing contaminant dispersion and transport. Fugitive emission rates may also be controlled by meteorological conditions and will fluctuate as the meteorological conditions change. An accurate determination of ambient air concentrations, therefore, should account for the atmospheric variability as well as the complex source configuration.

The program for evaluation of VOC concentrations around the site is to calculate ambient concentrations by modeling estimated surface flux emissions and measuring specific surface flux to validate projected results. A modeling program relies on the source data collected (such as VOC concentration gradients in the soil and soil permeabilities), empirical models to determine the emission rates, representative meteorological data, and dispersion model to determine downwind concentrations. Modeling is routinely performed for a variety of situations and is important for rapid assessment of contamination.

4.3.3 Vadose Zone

This section identifies data requirements that will be addressed in the RI/FS program for the vadose zone beneath and adjacent to the SDA. The documents cited in the section discussing known volatile organic contamination in the vadose zone (Section 3.3.3) were reviewed to evaluate the existing data base for the SDA and identify data gaps that will be filled during the RI/FS program.

Numerous studies have been conducted in which the surficial soils have been sampled, and the basalts and sedimentary interbeds have been logged or sampled. In addition, soil gas and soil water have been sampled and perched water zones have been encountered and also sampled. A discussion of the results of these investigations is presented in Section 3.3.3.

The results of these investigations have been incorporated into the computer modeling and CSM. The VOC contaminant transport media and mechanisms used in the computer modeling are identified in the CSM (See Figure 4-3). Initial estimates indicated that vapor transport mechanisms are the primary method of VOC migration in the vadose zone. Aqueous infiltration transport carrying dissolved VOCs may have been more significant in the past during prior flooding events; however, no data are available on these earlier events. Perched water measurements, and vapor port monitoring will be used to qualitatively assess other transport mechanisms. The vadose zone beneath the SDA is comprised of fractured basalt layers interspersed with interbeds of clay, sand, and gravel as shown in Figure 4-4. The basalt layers are comprised of Dense and fractured basalts containing zones of perched water. The 240-ft interbed is a continuous 6- to 33-ft-thick zone beneath the SDA. It also appears to be partially saturated for at least a portion of the thickness within the SDA. The 110-ft interbed is 0- to 30-ft thick beneath the SDA with it thinning down to virtually nothing west of Well 78-4. Portions of the 110-ft interbed appear partially saturated. Where perched water is located or the interbed is saturated, the basalt or interbed retards vapor transport because the porosity is filled with water. However, the saturated intervals are not laterally or vertically extensive and contain relatively small volumes of water. Reductions in the rate of VOC vapor movement downward through the 110-ft and 240-ft interbeds and surrounding zones because of saturated or low-permeable zones would affect the relative VOC flux of these pathways and their resulting risks.

The gaseous and aqueous transport properties of the vadose zone vary between the various horizontal layers. The transport properties within each layer also vary considerably. For example, the hydraulic conductivity of the 110-ft and 240-ft interbeds varies by six orders of magnitude beneath and adjacent to the SDA. Measurements were taken on 22 cores from 10 wells, and they ranged from 2.2×10^{-5} to 9.8 ft/day for the 110-ft interbed, and 2.6×10^{-6} to 8.9 ft/day for the 240-ft interbed. Consequently, local measurements of transport properties in the vadose have limited applicability because of the high level of variability. What is needed is a measure of the VOC effective transport of properties (e.g., permeability, effective porosity, fracture density, moisture content, etc.).

Computer modeling can be used to determine the effective transport properties of horizontal layers within the vadose zone. The effective transport properties of low permeable layers are estimated from the measured vertical concentration gradients of the VOCs. The ratio of horizontal to vertical diffusivity within the VOC plume is estimated from horizontal and vertical concentration
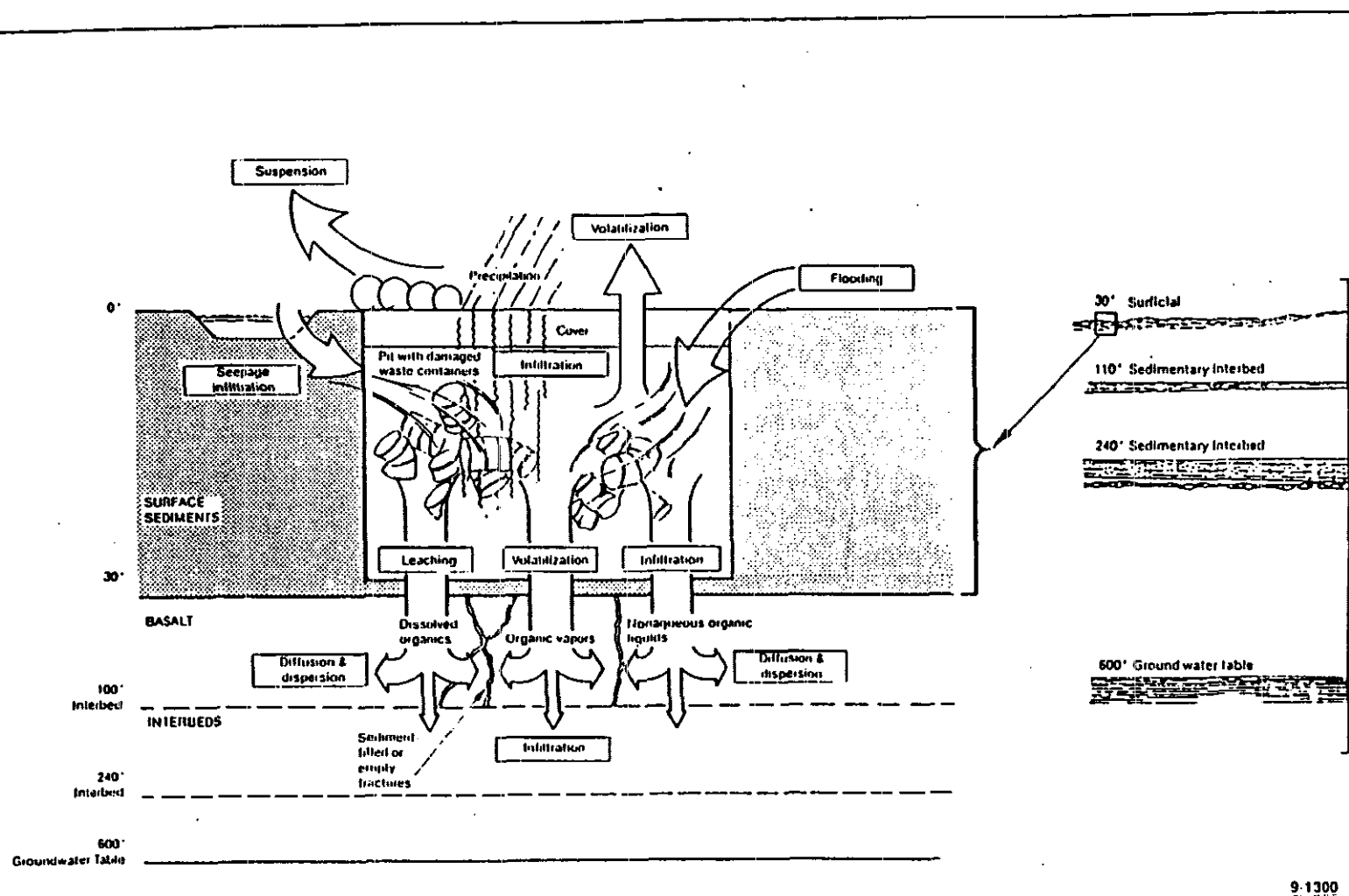
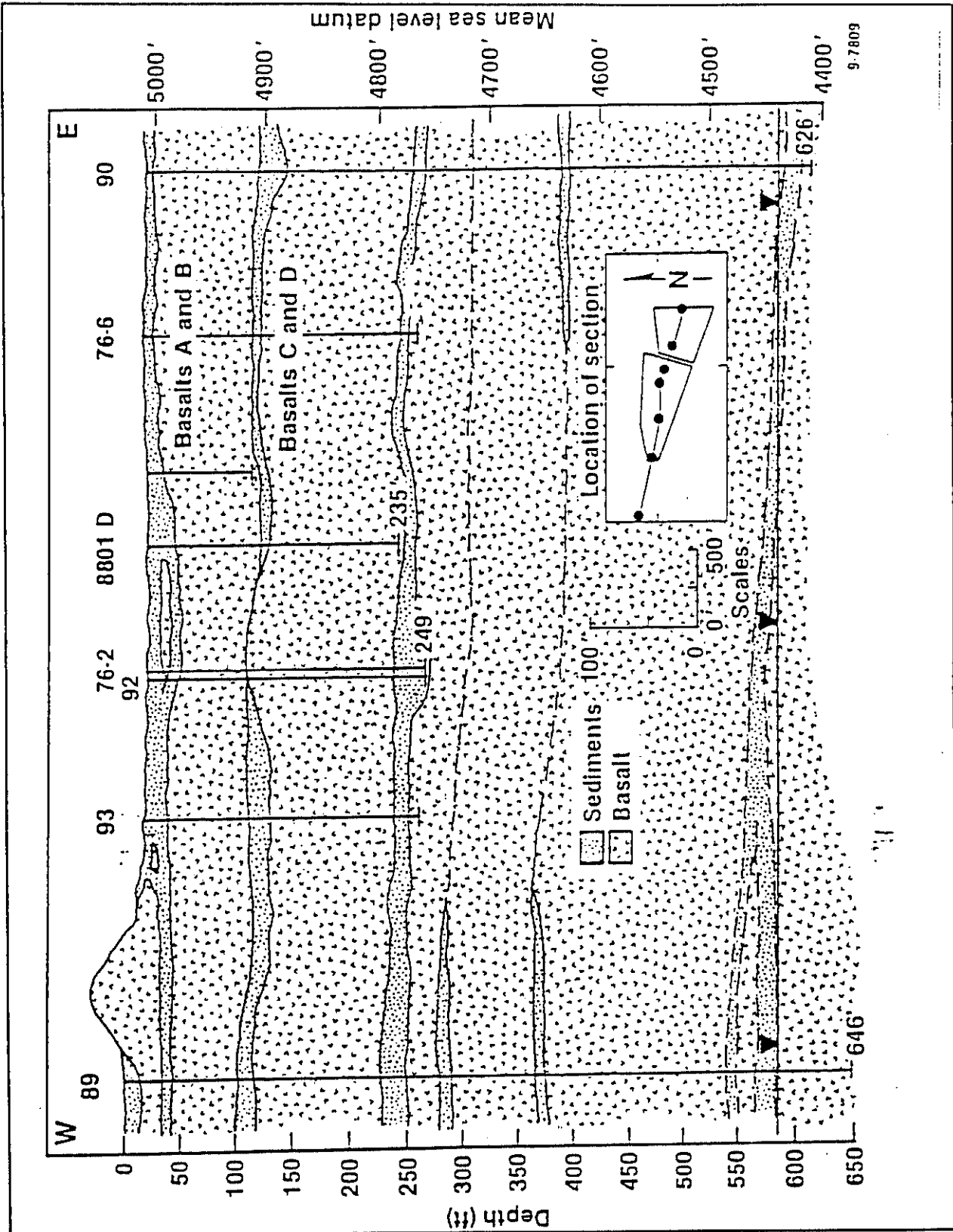**Figure 4-3.** Conceptual site model of vapor transport.

Figure 4-4. Surficial sediments and interbeds at the RWMC.

gradients and areal and vertical extent of the vapor plume. The VOC vapor plume is used as a tracer. The VOC concentration results from the vapor monitoring ports and the projected VOC release from drums are used to calibrate the computer modeling and estimate the rates of gaseous localized vapor diffusion within the vadose zone.

The Focused RI/FS SAP has been developed to fill the gaps identified in the existing data base for the OCVZ at the SDA. Based on a preliminary review of existing data, a number of deficiencies have been identified in the data collected to characterize the vadose zone. The following deficiencies in the data are presented below and have been addressed in the plan for characterizing the site during the Focused RI/FS:

- The distribution and concentrations of volatile organic contaminants in the soils, basalt, and sedimentary interbeds have not been fully defined and are needed to determine the extent of the VOC plume and to perform the risk assessment and to evaluate remedial alternatives in the FS.

- The physical properties of the basalt flows in the vadose zone, including vertical and horizontal hydraulic conductivity, air permeability, and porosity are not well defined.

- The changes in permeability and porosity between basalt flows, and between basalt flows and sedimentary interbeds are not well defined and will affect the presence, location, and extent of perched water zones.

- The presence and distribution of volatile organic contaminants in the basalts and sedimentary interbeds underlying the SDA have not been adequately characterized and consistently monitored.

- A consistent program for sampling and analysis of perched water for volatile organic chemicals has not been performed. Resulting data gaps include soil-water or rock-water interactions and their effect on contaminant migration through the perched water zones. Additionally, hydraulic properties of the perched water zones are not well defined.

- Preliminary projections of VOC fluxes to the atmosphere and groundwater have been calculated for the vadose zone at the SDA. Additional information on the physical, hydraulic, and geochemical properties of this zone is needed to confirm these values.

4.3.4 Groundwater

This section identifies groundwater data requirements that will be addressed in the RI/FS for the OCVZ beneath the SDA. Several monitoring wells have been installed surrounding the SDA and provide preliminary information to develop a general understanding of the groundwater dynamics near the SDA and to establish the basis for future site characterization decisions. The information from the Groundwater Track II will be used for the OCVZ risk assessment, treatability study, and feasibility study.

Since 1987 eight groundwater monitoring wells around the RWMC have been sampled for VOCs. One sample has indicated concentrations above the regulatory limit of 5 μg/L carbon tetrachloride. All subsequent samples from that well have been below the MCL limits for carbon tetrachloride. Simulations of VOC transport processes indicate that VOC concentrations in the groundwater can be expected to increase over several years and peak sometime in the next century, if no action is taken to treat the VOC plume under the SDA. Thus, maintaining groundwater quality within regulatory limits will require either reducing the concentrations in the subsurface plume or treating ground water at a future date.

The data collected from the proposed RI is intended to be used to

- Quantify the magnitude and horizontal and vertical extent of volatile organic contamination in the SRPA.

- Assess potential exposure impacts

Several groundwater studies have been conducted near the SDA. Even with these studies, the existing data base has a number of deficiencies. The data gaps pertaining to groundwater and its contaminants inhibit the development of a comprehensive understanding of site hydrology in order to meet regulatory requirements. These data gaps are identified below and are being addressed by the following Groundwater Operable Unit Track II (OU 7-06) activities

- The direction of groundwater movement beneath the SDA is poorly defined at the local scale. Better definition of the flow field at the SDA and local gradient reversals is needed.

- The presence and effects of vertical groundwater gradients at the SDA have not been characterized. There appear to be no data regarding potential vertical movement of water/contaminants in the aquifer system.

- The total thickness of the Snake River Plain Aquifer is not known. The vertical extent of the aquifer has not been determined at the SDA.

- The partitioning of contaminants in the aquifer (i.e., floaters, sinkers, and miscible) is unknown.

- The effects of the geologic controls (such as basalt fracture patterns and interbeds) on groundwater movement in and around the SDA are poorly understood. Additional field data are needed to characterize stratigraphy and aquifer properties beneath and adjacent to the SDA.

- Pathways of volatile organic contaminant migration (horizontal and vertical) in the aquifer need to be better defined at the local scale. (This is very closely related to determining local and regional flow gradients).

- A water budget evaluation is necessary for developing conceptual and mathematical models of water flux and volatile organic contaminant migration in the aquifer beneath the SDA.

- Geochemical processes affecting the fate and transport of known and suspected volatile organic contaminants in the saturated zone have not been adequately characterized.

4.3.5 Computer Modeling

The purpose of this section is to give an overview of the modeling methodology and modeling efforts intended to support the objectives of the OCVZ Focused RI/FS at the Radioactive Waste Management Complex (RWMC). Modeling efforts support two activities: (1) the baseline risk assessment, and (2) the remediation evaluation. However, much of the data required to support one are also required for the other. Past modeling studies that addressed the organic contamination at the SDA (Walton et al. 1989, Baca et al. 1988) have supported both of these activities.

Modeling will be used to expand empirical data collected to answer specific objectives of the RI/FS. Simple models are based on available data, and sensitivity analyses are performed to obtain a qualitative (and quantitative where possible) understanding of the vadose zone. Specific modeling will be tailored to each objective and will utilize several approaches. Modeling will be performed in a phased approach; an initial qualitative understanding of the site will be followed by a more quantitative analysis, if the available data and end use of the information warrant it. Sensitive parameters will be determined and analyzed as characterization proceeds. Parameters will include, but are not limited to, infiltration rate, source term release rate from waste, effective diffusivity, and effective VOC source area for the groundwater model.

4.3.5.1 Modeling to Support Risk Assessment. The objective of a risk assessment is to quantify exposure to receptors. This requires sufficient data be collected to determine the spatial and temporal extent of contamination at receptor locations. It is not always feasible to collect enough data to satisfy this requirement. Present risk can be estimated by current VOC measurements in the vadose zone but those measurements do not predict the future. To make these predictions it is necessary to supplement field data with fate and transport modeling. Models make use of available lab and field data and physical and chemical principles to estimate data which is otherwise impractical to obtain.

To perform a quantitative risk assessment, the VOCs released to the environment in each medium must be estimated. The two major pathways for exposure from VOC contamination are the air and groundwater. Modeling supports the quantitative risk assessment by providing estimates of VOC flux to the atmosphere and to the aquifer from the vadose zone. Estimates use vadose zone concentration data, interpolation, and simple equilibrium and/or process models. For example, VOC flux to the air and groundwater can be roughly estimated using steady-state diffusion models and vapor concentrations in the vadose zone. If there is sufficient data, aqueous transport (groundwater pathway) and barometric pumping (air pathway) may be added to the process models. The fluxes are then used in other models to calculate air and groundwater exposures to be used in the risk assessment. Air and groundwater concentrations can be approximated using simple box and/or

dispersion models. Box models are used for near source receptors and assume fugitive emissions are mixed in a rectangular control volume to calculate average ambient concentrations.

To determine future risk, some knowledge or estimate of the rates and directions of contamination movement under predicted ambient conditions is imperative. This can be done by modeling the growth and spread of the VOC plume in the vadose zone from time of disposal until present. The appropriate model and processes would be determined by site specific historical, geographical and hydrologic data. The predictive capability of the model would be enhanced by matching field data (i.e. vadose zone vapor concentrations, groundwater concentrations, and surface flux measurements) with predicted output. This calibration requires adjusting model parameters until model output agrees with field measurements. From this information, past and future VOC fluxes to the atmosphere and groundwater can be estimated.

Earlier studies by Walton et al. (1989) used simplifying assumptions to model the growth of the VOC plume using what can be called a limited parameter model. The model was judged acceptable in terms of complexity for the purposes of this study by an independent peer review panel (Robertson et al., 1990). The modeling processes, assumptions, and the site transport parameters are discussed in the following section.

4.3.5.1.1 Model Theory and Assumptions (Vadose Zone).

In the vadose zone, organics can exist in three phases: (1) a nonaqueous liquid phase, (2) an aqueous liquid phase, and (3) a vapor phase. Baca and Walton (1988) have suggested that for the RWMC and the type of organic waste disposed there, the transport of organics occurs in the following order of importance (vapor transport > aqueous transport > nonaqueous transport). Each of these phases can move by different mechanisms. Aqueous phase advective transport is directly related to the patterns of water flow in the subsurface. The climate at the RWMC is quite dry and infiltration is only a few centimeters per year. Therefore, aqueous advective transport is restricted due to the low soil-moisture content, and water flow rate. Aqueous phase diffusion is also limited because of the low-moisture content and the fact that aqueous diffusion is three to four orders of magnitude smaller than vapor-phase diffusion. However, partitioning of the organic vapors into the water phase could be a significant factor controlling vapor movement at the RWMC.

Nonaqueous transport is dependant upon the viscosity of the liquid wastes. The Rocky Flats organic waste buried at the RWMC contained a significant amount of viscous machine oil. Prior to shipment from Rocky Flats, this waste was mixed with calcium silicate and packed in 55 gallon drums. The calcium silicate turned the mixture into a semi-solidified paste. This solidification process, the high viscosity of the oil, and lack of nonaqueous phases found in the vadose zone are justifications for considering the nonaqueous liquid phase to be relatively immobile.

Transport of contaminants in the vapor phase can occur by advection, dispersion, and diffusion, and is affected by partitioning with the solid and water phases. Advection is the result of pressure and density gradients in the gas mixture. Usually the only significant pressure gradients are near the surface due to fluctuations in barometric pressure. They account for venting of the gas to the atmosphere. During vapor extraction operations, however, pressure gradients induced by the extraction process are larger and advection is the principal mode of transport. Density gradients

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result when the soil gases (usually air) are contaminated with another gas of a different molecular weight. The density driven flow will be upward if the molecular weight is less than air, and downward if the molecular weight is greater than air. Since the molecular weights of the VOCs of concern are greater than air, the movement should be downward. The principal VOC at the RWMC is carbon tetrachloride which has a molecular weight approximately five times that of air. The velocity of the flow is a complicated function of the chemical's vapor density (i.e., concentration), the permeability of the media, and the degree to which the vapor is partitioned into the water and solid phases. For the relatively dilute vapor concentrations measured at the RWMC, the density driven flow is estimated not to be significant. However, this will be investigated to determine the relative contribution of density driven flow to the overall transport of the VOCs.

Dispersion is a spreading process caused by the mechanical mixing of solute during fluid motion. It is caused by velocity variations due to: (1) the drag forces exerted on the fluid by individual pore walls, (2) heterogeneities in the media, and (3) the branching of the flow paths. This process is usually important at flow velocities higher than those predicted at the SDA.

For waste migration, vapor phase diffusion was considered to be the dominant mode of transport. As Baehr (1987) observes, halogenated hydrocarbons such as trichloroethylene (TCE) and carbon tetrachloride (which account for the majority of the Rocky Flats organic wastes at the RWMC) can be significantly transported by diffusion because of their high vapor pressures. Other researchers have also identified vapor diffusion to be an important transport mechanism for volatile organics (Farmer et al., 1980; Weeks et al., 1982; Marrin and Thompson, 1984).

Other processes that can affect the migration of organics and act to retard their movement are natural degradation and sorption of the organics onto the porous media matrix. Early studies by Lambert (1968), and more recent experiments by Mehran et al. (1987), have demonstrated that sorption of organics is controlled by the amount of natural organic content in the porous media. The organic content of the basalts beneath the RWMC is quite low and thus sorption is assumed to be low. Natural degradation does not appear to be a significant retarding mechanism either as carbon tetrachloride vapor is quite stable with a degradation time of about 7000 years (Vogel et al., 1987).

To summarize, the processes thought to be contributing to organic movement and the subsequent formation of a subsurface plume at the RWMC are vapor and aqueous phase transport, with vapor transport being predominant. Of the vapor transport mechanisms, molecular diffusion contributes to the greatest degree, with mechanical dispersion, and density induced advection to a lesser degree. Aqueous advective flow should have a minor effect assuming natural infiltration; however, partitioning of the vapor in regions of higher moisture content will retard the transport. Adsorption and degradation do not appear to be important retardation mechanisms.

4.3.5.1.2 The General Transport Equation (Vadose Zone).

The information and processes summarized in the previous section can be incorporated into a general transport equation. Application of this equation to the RWMC will yield information about the rates and directions of VOC movement. The governing equation for conservation of a contaminant can be written as

$$\frac{\partial C}{\partial t} = -\vec{\nabla}\cdot\vec{q} + S_c - \lambda C.$$

This is the governing equation for contaminant transport in a porous media, derived on a macroscopic level. $\partial C/\partial t$ is the time rate of change of the contaminant, $\vec{q}$ is the contaminant flux, S_c is the mass generation or contaminant source term and λC is a decay or sink term. Neglecting free liquid contaminant transport, the contaminant, C, may be partitioned between the solid matrix, the soil water, and the soil gas. Defining ϕ_s, ϕ_w, and ϕ_g, as the solid, water, and gas filled porosities; and C_s, C_w, and C_g, as the solid, water, and gas concentrations, the mass of the contaminant per unit volume of porous media can be written as

$$C = \phi_s C_s + \phi_w C_w + \phi_g C_g.$$

For simplicity, local equilibrium is assumed between the solid, aqueous, and gas phases. This means that any change in the concentration of one of the phases is accompanied by an instantaneous corresponding change in the concentration of the other two phases. This being the case, it is assumed that the contaminant in the aqueous and gas phases is partitioned according to Henry's law

$$C_g = HC_w$$

where H is the Henry's coefficient. A similar relationship based on a linear adsorption isotherm is assumed to approximate the partitioning between the solid and aqueous phases

$$C_s = K_d C_w$$

where K_d is the partition or sorption coefficient. The mass per unit volume of porous medium can then be written as

$$C = \phi_s \frac{K_d C_g}{H} + \phi_w \frac{C_g}{H} + \phi_g C_g.$$

Recalling that sorption could be neglected due to the low carbon content of the basalts beneath the RWMC, the equation can be rewritten as

$$C = \phi_g C_g \left(\frac{\phi_w}{\phi_g H} + 1 \right)$$

which can be further reduced to

$$C = \phi_g C_g R_d$$

where R_d is commonly known as the retardation coefficient. For a moving fluid the retardation coefficient is the ratio of the fluid velocity to the velocity of the contaminant. It represents the capacity of the media to store the contaminant similar to the specific heat of a substance being a measure of its capacity to store heat. A retardation coefficient equal to 1 describes a situation where there is no sorption or aqueous partitioning and thus the contaminant is unretarded. A retardation coefficient greater than 1 denotes sorption is taking place.

The flux, $\vec{q}$, in the original transport equation is the sum of the diffusive, dispersive, and advective fluxes.

$$\vec{q} = \vec{q}_m + \vec{q}_d + \vec{q}_v$$

Using Fick's law the diffusive flux is given by

$$\vec{q}_m = -\phi_g \tau D_m \vec{\nabla} C_g$$

where D_m is the molecular diffusion coefficient and τ is the tortuosity factor. The tortuosity factor is a number less than or equal to 1 and accounts for the extra distance covered by a fluid traveling a tortuous path through the void spaces of a porous media.

Similar to the diffusion expression, the dispersion term can be written as

$$\vec{q}_d = -\phi_g D \vec{\nabla} C_g$$

where D is a second order tensor called the coefficient of mechanical dispersion. Mechanical dispersion accounts for variations in velocity at the pore scale. Because this process is velocity dependent, it is most important during VVE operation and not during migration under ambient conditions.

The remaining fluxes considered are expressed as advection in the gas phase, and advection in the aqueous phase

$$\vec{q}_v = \phi_g \vec{v}_g C_g + \phi_w \vec{v}_w \frac{C_g}{H}$$

where $\vec{v}$ is the average pore velocity of the gas or water. Note the aqueous concentration has been expressed using Henry's law.

The contaminant concentration equation can now be written upon substitution of the partition equation and the flux equations into the original balance equation.

$$\frac{\partial(\phi_g C_g)}{\partial t} = \frac{1}{R_d} \vec{\nabla} \cdot \left[-\phi_g \vec{v}_g C_g - \phi_w \vec{v}_w \frac{C_g}{H} + \phi_g (\tau D_m + D) \vec{\nabla} C_g \right] + S_c$$

Note the sink term has been dropped and the equation has been written conveniently in terms of the gas phase concentration. Although the equation may look complex, it can be simplified even further by considering only the dominant flux terms. For simple geometries and sufficiently constrained problems, the equation (or parts of it) may be solved rather easily by analytical means. The equation may also be solved easily using numerical methods. With a few modifications to coefficients, the transport equation can be solved using a relatively general purpose "off the shelf" computer program. The program must be able simulate advective and/or diffusive transport of a single phase contaminant in a saturated porous medium (preferably in more than one dimension).

The computer program proposed for solving the equation is PORFLOW version 2.3 (Runchal and Sagar 1990). PORFLOW is capable of solving the combined fluid flow, heat and mass transport equations in geologic media. It was developed in support of environmental remediation activities being conducted at the Hanford Site. Version 1.0 of PORFLOW has been thoroughly tested (Magnuson et al. 1990a) by verification with analytical solutions and benchmark testing with numerous other computer codes such as FLASH, TRACR3D, FEMWATER, SUTRA, and TOUGH.

PORFLOW uses an integrated finite-difference formulation to discretize the process equations into a set of linear algebraic equations and PORFLOW is also equipped with several solution algorithms to choose from. PORFLOW has been used at several DOE sites for both saturated and unsaturated zone studies. PORFLOW's ability to reliably predict gas transport has been demonstrated by simulating two gas injection experiments here at the INEL (Magnuson et al. 1990b).

The mass transport equation from the PORFLOW user's manual is as follows.

$$\frac{\partial(\phi R_d C)}{\partial t} + \vec{\nabla} \cdot (\vec{V} C) = \vec{\nabla} \cdot [(\phi \tau D_m + \phi D) \nabla \cdot C] + S_c - \phi \lambda C$$

Assuming R_d is not a function of C and dropping the sink term, this equation resembles the derived equation except for the advective term. In the single phase mode, PORFLOW uses only one advective flux term. In the derived equation, the advective gas flux is accounted for even though as previously discussed; the consequence of this transport mode under normal conditions is assumed small when compared to diffusive flux contributions. The importance of aqueous advection will be determined by comparing results of simulations both with and without water flow. This process could likely be important on the fringes of the plume where concentration gradients are low and diffusion effects are less. Information from the Groundwater Pathway OU will be used to evaluate these processes. Therefore, it will be judged on how it affects the contaminant fluxes to the air and groundwater pathway (i.e. a 10 percent change would be deemed important). To implement the aqueous advection in PORFLOW the following substitution is used.

$$\vec{V} = \frac{\phi_w \vec{u}_w}{H}$$

This substitution into the PORFLOW transport equation makes it an equivalent expression to the derived contaminant transport equation assuming no advective gas flow. If it is determined that advective gas flow is important, the advective flux term would have to be modified to account for both the dissolved aqueous phase and the gas phase (simple modification) or it would be necessary to solve a two phase problem. If a constant water infiltration is assumed and density effects are small, it is not necessary to solve the two phase problem or even the flow equation. If a more thorough examination of aqueous phase transport is necessary such as simulating a flood, then it may be necessary to simulate a two-phase problem. But as a first approximation to large-scale aqueous transport, the problem could be simulated by more simple methods such as superimposing aqueous flow fields of increasing magnitude over the domain. This would yield a better understanding of the importance of such temporal aqueous events and will indicate the sensitivity of infiltration.

The transport equation has been simplified by assuming diffusion dominated flow in an unsaturated region where the resulting pore space is saturated with a single phase, isothermal binary gas. Since carbon tetrachloride has been detected in nearly all of the vadose zone vapor monitoring ports, the model should be calibrated with carbon tetrachloride data. The model can then be used to simulate the movement of each of the other contaminants separately. The transport equation can be solved in one, two, or three dimensions. The mass transport equation in its expanded three-dimensional form written in cartesian coordinates is:

$$\phi_s R_d \frac{\partial C}{\partial t} + \frac{\partial (UC)}{\partial x} + \frac{\partial (VC)}{\partial y} + \frac{\partial (WC)}{\partial z}$$

$$= \frac{\partial}{\partial x}\left[\phi_g(\tau_x D_m + D_x)\frac{\partial C}{\partial x}\right]$$

$$+ \frac{\partial}{\partial y}\left[\phi_g(\tau_y D_m + D_y)\frac{\partial C}{\partial y}\right]$$

$$+ \frac{\partial}{\partial z}\left[\phi_g(\tau_z D_m + D_z)\frac{\partial C}{\partial z}\right] + S_c$$

where U, V, and W are the Darcy velocities in the x, y, and z directions respectively. This is the selected model equation for simulating VOC transport in the vadose zone. In the case of uniform aqueous infiltration, only the Darcy velocity in the negative z (downward) direction is important.

Walton et al. (1989) studied the release of the VOCs from the containers and the waste pits and determined that for the relatively high vapor pressure compounds disposed at the SDA, the release was governed primarily by container failure. Release from the containers is determined by writing a mass balance for the organic waste inventory, C_i, in the containers

$$\frac{dC_i}{dt} = IX_i \epsilon - \lambda_d C_i$$

where I is the rate of waste input, X_i is the mole fraction of the i_{th} component, ϵ is the fraction of containers that do not fail at burial, and λ_d is the container failure rate constant. Solution of the equation for the burial or emplacement period, $(t < t_e)$, and the post-emplacement period, $(t > t_e)$, yields

$$C_i = \frac{IX_i \epsilon}{\lambda_d}[1 - e^{(-\lambda_d t)}] \qquad (t < t_e)$$

$$C_i = \frac{IX_i \epsilon}{\lambda_d}[1 - e^{(-\lambda_d t_e)}]e^{[-\lambda_d(t - t_e)]} \qquad (t > t_e).$$

The release rate, ζ, from the containers can then be calculated by

$$\zeta_i = IX_i(1 - \epsilon) + \lambda_d C_i \qquad (t < t_e)$$

$$\zeta_i = \lambda_d C_i \qquad (t > t_e).$$

The initial failure rate of the containers, $(1 - \epsilon)$, has been estimated to be about 20% and the corrosion failure rate, λ_d, to be 3.2×10^{-9} per second. The corrosion rate was estimated from drum retrieval studies at the RWMC. The initial container failure rate is the least understood component of the source term equations. It is therefore recommended that this uncertainty be recognized and the sensitivity of the parameter be examined should this level of modeling be considered appropriate and warranted.

4.3.5.1.3 Modeling the Geology/Lithology at the RWMC. Reviews of existing data on the stratigraphy and structural geology beneath the RWMC are being performed. The subsurface of the RWMC area has been studied by a number of researchers (Barraclough et al., 1976; Humphrey, 1980; US Department of Energy, 1980; Rightmire and Lewis, 1987; Anderson and Lewis, 1989; Knutson et al., 1990) and is discussed in detail in Sections 2 and 3 of the RI/FS work plan. According to these reports, the subsurface of the SDA is a sequence of layered basalt flows, cinders, and sedimentary interbeds of varying thickness and composition. The RI/FS objectives will establish the degree of subsurface characterization and transport modeling. The PORFLOW code is capable of incorporating stratigraphic layering of varying thickness to reflect the variation in properties measured at the SDA.

The transport properties of the basalt flows and interbeds are known to vary spatially. Transport property data collected has been on small core samples. Due to the difficulty and expense of obtaining a large number of samples the degree of spatial variability may never be well known. This could make estimating transport properties for modeling purposes quite difficult. Transport modeling can be facilitated by defining zones of common hydrologic and transport properties that are significantly different than neighboring regions. These zones generally coincide with the major stratigraphic features of the subsurface. By doing this, the properties for each zone become effective properties on a macro or field scale.

Some basalt flows beneath the SDA highly fractured both horizontally and vertically. If the fracturing is extensive the net effect of the heterogeneity may create a macro-porosity system where the blocks of basalt act like sand grains in a sedimentary system. The VOC vertical concentration profiles from monitoring wells near the burial pits are very similar in shape. These data suggest that the plume is rather diffuse and it's movement under ambient conditions is controlled by differences between individual basalt flows and interbeds and not heterogeneities or distinct fractures in individual flows. Core logging, basalt tracer studies, vapor port permeability measurements and extraction well flow measurements will test that hypothesis.

4.3.5.1.4 Modeling VOC Transport in the Aquifer. To model transport of VOCs in the SRPA for the purposes of risk assessment, simple models will be applied. The appropriate model will depend primarily upon aquifer characteristics and the location of the future RME individual. To estimate current risk for locations near the source, simple box or control volume mixing models would be appropriate. For future risk scenarios and downstream receptors, dispersion models will be used. The dispersion model is derived from an analytic solution to the groundwater solute transport equation (Codell and Duguid 1983). This is the same model used by Walton et al. (1989) and written into a general purpose computer code by Rood (1992) called GWSCREEN. The model assumes constant, unidirectional flow in a homogenous aquifer of infinite lateral extent and finite thickness. Sensitivity analysis will be done on the transport modeling. Parameters will include, but are not limited to, infiltration rate, source term release rate from waste, effective diffusivity, and effective VOC source area for the groundwater model.

4.3.5.2 Modeling to Support Remediation Design. The design and operation of a remediation system such as a vapor extraction system can be aided by appropriate analysis and modeling. Modeling a vapor extraction system is different than modeling done for a risk assessment.

The movement of VOCs by vapor extraction is dominated by gas advection (pressure-induced flow). Diffusion, which is important under ambient conditions, negligible within the influence of an extraction well.

Although modeling vapor extraction processes can be done separately, system design will rely on results which are important to risk assessment. The growth and spread of the organic vapor plume is controlled by container failure rate and diffusion rates of VOCs into the soils and basalts. The results of the growth phase determine the VCOs to be removed. The cleanup time depends on the nature, extent and volume of the plume. The cleaned up criteria also depends upon transport under ambient conditions, since it determines the fluxes to the receptors. When the extraction pumps are turned off, the residual contamination in the subsurface will continue to migrate. The level of contamination allowed to remain must be established from the same analysis used to support the baseline risk assessment.

To determine the feasibility of VVE remediation and design an effective system, it is advantageous to be able to estimate vapor flow rates, mass removal rates, and the time required to achieve a given level of remediation. In general, this requires knowledge of the contaminant locations relative to the vapor flow paths introduced by extraction wells. Current levels and locations of the contamination can be determined by sampling. Flow paths however are determined by the geologic and hydrologic make-up of the subsurface, induced vacuum, and construction of the extraction wells. The flow paths and vapor flow rates can be estimated from a combination of tracer tests and pressure measurements during operation. This information can in turn be used to estimate flow and transport parameters for modeling. Modeling can then be used to examine other conditions such as vertical extraction zones, well placements, and operating parameters.

To support the Treatability Study and design of a VVE remediation system, a phased modeling approach will be used. First, simple screening models will be used to estimate the performance of soil venting operations and to interpret the results of field tracer tests, and pump tests to determine air permeability/conductivity. These models however assume simple geometries and may not yield the necessary information to understand the system. As knowledge of the flow system and the controlling factors increases, it would be worthwhile to include effects of a heterogeneous and "layered" subsurface.

4.3.5.2.1 Model Theory and Equations (Remediation).

The design of most VVE systems is done by constructing a site-specific prototype system to determine critical parameters. As VVE systems become more widely used, models are being developed to assist in the design and implementation of them. Currently, there are relatively few models developed solely for investigating VVE systems. Aside from a few exceptions, the VVE physical processes are similar to those of groundwater pumping systems. Researchers (Krishnayya et al., 1988; Wilson et al., 1988; Croise et al., 1989; Massmann, 1989; and Johnson et al., 1990) have all demonstrated that groundwater (porous media) flow models based on Darcy's law provide good approximations to gas flow if the pressure difference anywhere in the flow field is less than 0.2 atmospheres. Since most VVE systems operate at pressure differences under 0.2 atmospheres, equations derived for incompressible fluid flow in a porous media can be used to model the gas flow so long as coefficients and variables (specific storage, permeability and pressure) are expressed appropriately.

The general equation for single phase, isothermal, slightly compressible fluid flow in a porous media can be written as

$$S_s \frac{\partial P}{\partial t} = \vec{\nabla} \cdot [K(\vec{\nabla}P + B\vec{\nabla}z)] + m_v$$

This equation is derived from Darcy's law and mass conservation principles.

where: S_s is the specific storage coefficient,

P is the hydraulic head,

K is the hydraulic conductivity,

B is the density disparity term, and

m_v is the fluid volume injection/extraction rate.

For VVE simulations, the density disparity or gravity term can usually be neglected. Johnson et al. (1990) simplified the equation further by assuming steady, radial flow in a confined, homogeneous, porous stratum of known thickness. That simplification resulted in simple screening models to be used in evaluating VVE systems. These models can be used to predict: pressure distribution, vapor flow rates, vapor velocities, and the radius of influence around the extraction well. The radius of influence is defined as the radial distance where the subsurface pressure is equal to atmospheric pressure. These are useful models but their application is limited to the simple geometries mentioned before. To incorporate more complex geometries, the equation must be solved numerically. Initially, pressure and flow fields can be generated to gain a qualitative understanding of the extraction process, and important design parameters. The information produced from these studies should be helpful in interpreting additional data as it becomes available from further testing and operation of the extraction well. Furthermore, the updated information should be used to refine the original assumptions and property estimates that went into the preliminary studies. Application of this information will improve understanding of site geology and its influence on vapor transport rates and directions.

The same computer code proposed for risk assessment modeling can be used to model the more complex geometries discussed. Many of the same reasons for using PORFLOW to model plume growth and migration are applicable for vapor extraction modeling. PORFLOW is a powerful code which is widely used and well verified. Because PORFLOW is currently being used at EG&G, several post-processing routines for output are also available.

4.3.5.2.2 Modeling Parameters (Remediation).

The most important parameter for simulating vapor extraction processes is air conductivity or permeability and the inherent anisotropy associated with it. Air permeability is important because it determines how the vapor plume will respond to pumping. According to Massmann (1989), this is one of the most uncertain of the input parameters. Depending on the geologic material and presence of moisture, it's value can range over several orders of magnitude. Because of the fractured basalts, it is better to obtain large-scale permeability values from field tests rather than laboratory measurements on core samples. In a field test by Schmalz (1969) at another INEL site, horizontal permeabilities for basalt were estimated at about 0.1 to 183 darcys. These numbers contrast sharply with permeability estimates for RWMC basalt cores in the milli-darcy range as reported by Knutson et al., (1990). The field-scale

permeabilities can be determined indirectly by empirical measurements of pressure and flow in the extraction well and pressure measurements in a nearby monitoring well.

In light of uncertainties in the subsurface, sensitivity analyses should be conducted. Model predictions and remediation decisions should take into account these uncertainties. For example, the modeling of flow in fractured basalts has little theoretical basis. Heterogeneity and potential channeling effects are likely to be important in the basalts. High permeability zones could lead to over-prediction of VVE effectiveness and under-prediction of clean-up time. Currently there exists no satisfactory alternative to the equivalent porous medium assumption. The proposed tracer tests and pressure monitoring should help define the macroscopic implications and appropriateness of this assumption.

4.3.6 Organic Contamination

A number of VOCs were measured in the perched and groundwater and in the vadose zone gas phase. These contaminants included carbon tetrachloride (CCl_4), trichloroethylene (TCE), tetrachloroethylene (PCE), trichloroethane (TCA), chloroform ($HCCl_3$), 1,1,2-trichlorotrifluoroethane, etc. Some VOCs were specifically called out in the waste inventories (i.e., CCl_4, TCA, TCE, PCE.)

Within a preliminary qualitative risk assessment, the measured concentrations and toxicity of the VOCs were evaluated. The projected risks associated these compounds were estimated, and it was determined that carbon tetrachloride was the major risk with TCE also being a concern (about 10% of the carbon tetrachloride). While other VOCs are less of a risk due to their lower concentrations. The risks of other VOCs will be measured and combined with the risks due to carbon tetrachloride and TCE to accurately reflect the total risk of VOCs in the vadose zone. Since the other VOCs are not a major risk concern, they will be measured only periodically in the vapor ports. However, all purgeable CLP analytes will be measured in water that is sent to outside laboratories.

4.3.7 Summary of Data Gaps

The data gaps of the OCVZ were initially identified in the September 12 and 13, 1991, scoping meeting. The general data gaps include (a) VOC plume and transport data below the 240-ft interbed, (b) extent of the VOC plume including elevated VOC levels above the 240-ft interbed, (c) VOC migration from the buried drums into the vadose zone VOC plume, (d) vertical concentration gradient below 240-ft interbed, (e) vertical VOC concentration gradient above 50 ft, (f) VOC surface flux, (g) VOC flux to groundwater, (h) VOC "foot print" above groundwater, (i) effective aquifer thickness, (j) validated computer modeling, (k) prediction of effectiveness of the remedial alternatives, and (l) validation of transport properties of vadose zone. Data gaps include:

- Estimate how much of each VOC is present in the SDA today and the amount predicted to escape monthly/yearly in the future. This prediction should also indicate the pathway(s) for release of each constituent.

- Estimate the sensitivity of the release rate to the amount of VOCs remaining in the buried drums.

- Vertical concentration gradients of VOCs in surficial sediments.

- Flux of VOCs to atmosphere.

- The distribution and concentrations of volatile organic contaminants in the soils, basalt, and sedimentary interbeds have not been fully defined and are needed to determine the extent of the VOC plume and to perform the risk assessment and to evaluate remedial alternatives in the FS.

- The physical properties of the basalt flows in the vadose zone, including vertical and horizontal hydraulic conductivity, air permeability, and porosity are not well defined.

- The changes in permeability and porosity between basalt flows, and between basalt flows and sedimentary interbeds are not well defined and will affect the presence, location, and extent of perched water zones.

- The presence and distribution of volatile organic contaminants in the basalts and sedimentary interbeds underlying the SDA have not been adequately characterized and consistently monitored.

- The hydraulic properties of the perched water zones are not well defined.

- A consistent program for sampling and analysis of perched water for volatile organic chemicals has not been performed. Resulting data gaps include soil-water or rock-water interactions and their effect on contaminant migration through the perched water zones.

- Preliminary projections of VOC fluxes to the atmosphere and groundwater have been calculated for the vadose zone at the SDA. Additional information on the physical, hydraulic, and geochemical properties of this zone is needed to accurately calculate these values.

- Quantify the magnitude and horizontal and vertical extent of groundwater volatile organic contamination

- Assess potential exposure impacts

These data gaps are identified below and are being addressed by the following Groundwater Operable Unit Track II (OU 7-06) activities.

- The direction of groundwater movement beneath the SDA is poorly defined at the local scale. Better definition of the flow field at the SDA and local gradient reversals is needed.

- The total thickness of the Snake River Plain Aquifer is not known. The vertical extent of the aquifer has not been determined at the SDA.

- The partitioning of contaminants in the aquifer (i.e., floaters, sinkers, and miscible) is unknown.

- The effects of the geologic controls (such as basalt fracture patterns and interbeds) on groundwater movement in and around the SDA are poorly understood. Additional field data are needed to characterize stratigraphy and aquifer properties beneath and adjacent to the SDA.

- The data on hydraulic properties of the aquifer need to include data from pumping tests that stress the aquifer. The pumping tests at the RWMC have generally been performed with low pumping rates and with no observation wells.

- Pathways of volatile organic contaminant migration (horizontal and vertical) in the aquifer need to be better defined at the local scale. (This is very closely related to determining local and regional flow gradients.)

- A water budget evaluation is necessary for developing conceptual and mathematical models of water flux and volatile organic contaminant migration in the aquifer beneath the SDA.

- Geochemical processes affecting the fate and transport of known and suspected volatile organic contaminants in the saturated zone have not been adequately characterized.

4.3.8 Filling Data Gaps

Data gaps and supporting tasks to be performed in the Focused RI/FS have been prioritized. The specific tasks referred to by numbers are presented in detail in Section 5.3.

VOC migration from the buried drums into the vadose zone will be estimated by measuring VOC vapor concentrations adjacent to the waste pits (task 1). These results will be used to support the source projections made in the computer modeling.

New vapor ports installed with groundwater wells surrounding the SDA by the Groundwater Operable Unit will be used to define the extent and concentration of the VOC plume and the vapor transport properties below the 240-ft interbed (task 2).

Transport properties of 240-ft interbed will be addressed in the RI by measuring VOC concentration below and above 240-ft interbed (tasks 2) outside the SDA, and by using tracer tests through 240-ft interbed (task 10) outside the SDA. Existing information on the stratigraphy and structure of the vadose zone will be reviewed (task 8). Information on transport properties within the various stratigraphic layers will be identified and correlated with parameters in the computer modeling.

The extent of VOC plume above 240-ft interbed contains the zones of high concentrated VOCs. Further sampling of the VOC plume, particularly east and south of Extraction Well 8901 will be performed by monitoring existing open wells within the SDA (task 9). Plume concentrations between wells will be projected between monitoring ports using the computer modeling. The extent of elevated levels of VOC concentration, particularly above the 110-ft interbed and east and south of the extraction well, will be more fully defined within the SDA by monitoring exiting open well for VOC concentrations (task 9).

The vertical concentration gradient below the 240-ft interbed will be defined with the new vapor ports located below the 240-ft interbed but outside the SDA. Those ports are being installed by the Groundwater Operable Unit. The vertical concentration gradient above 50 ft will be determined in the vapor concentrations in soils (task 1). Shallow vapor measurements are highly affected by barometric pressure. Task 6 will measure the effect of increases and decreases of the barometric pressure on the VOC concentration in the vadose zone at 50 ft.

The VOC fluxes to groundwater will be projected by the computer modeling. These projections, which are used to quantify the exposure risk resulting from the groundwater pathway, will be supported by vapor measurement below the 240-ft interbed (task 2) and the groundwater quality measurements (task 10), which are being performed by both the USGS and personnel from the Groundwater Operable Unit.

The area though which the VOC flux migrates to the aquifer will be defined in order to estimate the contaminant mass loading to the groundwater. The areal extent of the plume just above the aquifer will be defined by the new vapor ports and new and existing groundwater wells (tasks 2 and 10).

The effective aquifer thickness, which is necessary to estimate the contaminant concentration in the groundwater, will be defined within the Groundwater Operable Unit (OU 7-06).

The computer modeling needs to be validated with empirical data defining the extent and concentration of the VOC plume beneath the SDA. The confidence level of the computer modeling increases with each data point validating the projected VOC vapor plume and transport properties. Data from continual monitoring of new and existing vapor ports will be used to validate the computer modeling (task 2). Gas permeabilities surrounding each vapor port will be measured (task 4) and correlated with computer modeling transport parameters.

Computer modeling is used to predict the effectiveness of the various remedial alternatives. Results from the treatability study and vapor transport properties (tasks 4 and 5) will be used to calibrate the VOC extraction option of the computer modeling.

Validation of the CSM and transport properties of vadose zone will be addressed in (tasks 2, 3, 4, 5, 7, 9, and 10,). The perched tasks (task 3) will result in estimates of aqueous movement in the vadose zone. The remaining tasks relate to vapor movement through the vadose zone.

The following activities (VOC surface flux, soil moisture and soil gas survey) will only be done if the first phase of field activities and review of those data determines that they are needed for the Baseline Risk Assessment to determine VOC being released to the air pathway. The VOC surface flux will be measured by with a flux chamber (task 12). The VOC surface flux is expected to vary considerably across the SDA; consequently, eight locations will be measured using the flux chamber. The flux locations will be identified with the prior soil-gas surveys, which defines the areal variation of VOC concentration. The vapor surface flux will be strongly affected by soil moisture, temperature, and meteorological conditions; consequently, soil moisture (task 13) and temperature (task 1) measurements will be made adjacent to the flux measurement locations. Meteorological data will be collected during the entire RI (task 7).

4.4 Remediation Alternatives

During the four-month extraction test the vapor concentration in Vapor Monitor Well 8801D was found to increase above the 110-ft interbed as seen in Figure 4-5. What appeared to be happening was horizontal movement of VOC vapor from a more highly concentrated zone west of the monitor well. The soil-gas survey in 1987 indicated a hot spot west of Well 8801D. This concentrated plume correlated with recorded locations of VOC containing drums buried in Pits 4 and 10 obtained from inventories and burial records.

The increase in the vapor concentration in Monitoring Well 8801D appeared to show no VOC increase resulting from vertical VOC movement. As seen in Figure 4-5 the vertical concentration gradient did not show a relative increase in shallow vapor ports as would indicate a downward movement of VOCs from the overlying pits. Consequently, it appears that the increase in the VOC concentration in Well 8801D was due solely to horizontal movement of the vapors. If the vapor plume can be moved horizontally with little vertical movement, the VVE will be most effective.

During the four-month test the extraction gas averaged only 36 ppm CCl_4 (Sisson and Ellis 1991) resulting in a low mass-extraction rate of CCl_4. During that test, over 80% of the extraction gas was removed from below the 110-ft interbed where the vapor concentration averaged about 40 ppm, which is similar to the extraction gas average concentration. By extracting from the 100- to 70-ft zone that contains concentrated VOCs, it is believed that the VOC concentration in the extraction well can be increased. The raised VOC concentration would increase the extraction rate resulting in a more cost-effective remediation system.

Computer modeling can be used to project the maximum VOC concentration in the vadose zone that will result in VOC contamination below Maximum Concentration Limits (MCL) in the groundwater or below (TLV) in the atmosphere. Using this approach, a risk-based cleanup criteria can be developed. The proposed cleanup criteria would vary with depth in the vadose zone. VOC plumes nearer the soil surface and the aquifer would result in higher fluxes to that pathway. Projections of VOC cleanup requirements would give project managers (Idaho Department of Health and Welfare, EPA, and DOE) contaminant values, upon which to base remedial actions. Those cleanup projections would also result in operational targets for the treatability studies and design criteria for the remedial design.
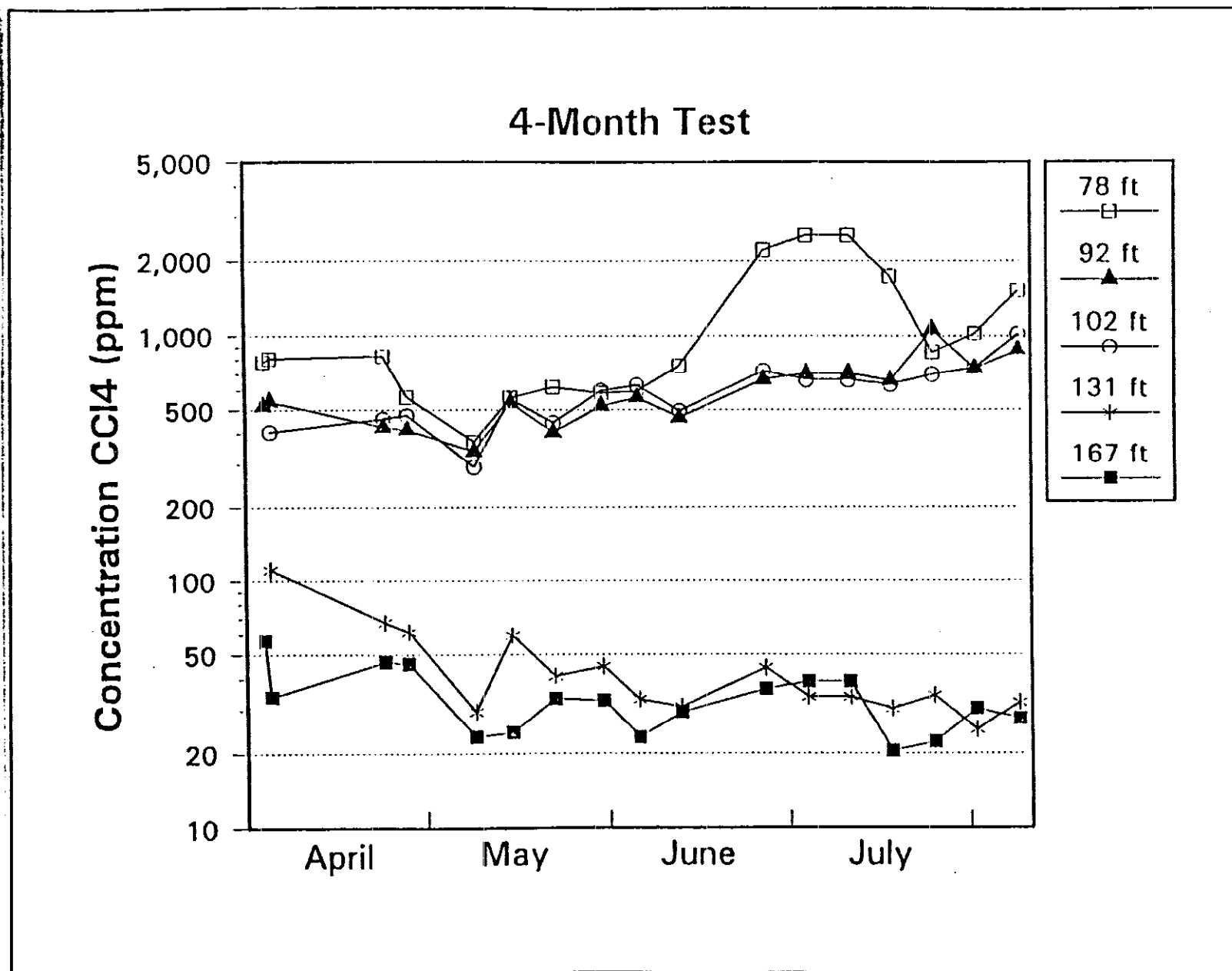
Figure 4-5. Carbon tetrachloride concentrations at Well 8801D during the four-month test.

4.5 Conclusions

The following conclusions were drawn in preparing the rationale for the Focused OCVZ RI/FS specific study tasks as they apply to data gaps prioritized in the March 12, 1992, meeting:

- The technical rationale and data usage of each sampling activity are defined and related to existing data.

- Data resulting from the RI activities will be utilized to estimate the extent of the VOC plume in the vadose zone, develop the baseline risk assessment, and support the VVE treatability study.

- Computer modeling will be used to extend empirical data and to predict future events as required by plume definition, risk assessment and treatability study activities.

- Flux projections developed from empirical data and computer modeling will be used in the risk assessment.

- Carbon tetrachloride and TCE are the major contaminants of concern, but the risks caused by other VOC contaminants will be included in the risk assessment.

- Local measurements of vadose zone transport properties have limited applicability to the RI/FS due to their high spacial variability.

- Measurements of the VOC plume concentration and extent can be used to define effective transport parameters for zones of common transport properties in the vadose zone.

- The distance from the VOC source to the groundwater (approximately 500 ft) and the VOC transport rate result in the maximum VOC flux to the groundwater occurring in the future.

- The maximum flux to the atmosphere is projected to have occurred in the past.

- Empirical data and computer modeling will be used to develop cleanup criteria for the vadose zone.

- Remedial alternatives that may be proposed for the RI/FS include (a) VVE, (b) in situ bioventing, (c) excavation, and (d) no action.

- No drilling through the 240-ft interbed within the SDA.

A summary of the correlation between pathway priorities, field activities, and data gaps for the organic contamination in the vadose zone operable unit is shown in Table 4-8.

Table 4-8. Correspondence between pathways priorities, field activities, and data gaps for organic contamination in the OCVZ Operable Unit.

Pathway	Field activity	Data gap
Air		
	Vapor pressure and temperature in vadose zone/pits	Vertical VOC vapor concentration gradient VOC surface flux Estimate of VOC vapor pressure in pit
	Diffusion/permeability of VOCs in vadose zone (tracer tests)	Transport of VOCs in basalt Transport of VOCs in sedimentary interbeds
	Packer tests (in open wells)	Vertical VOC vapor concentration gradient Vertical and horizontal extent of VOCs
	Shallow well vapor ports	Vertical VOC vapor concentration gradient Vertical and horizontal extent of VOCs Transport of VOCs in soil
Groundwater		
	Groundwater analysis for VOCs/elevations (multiple completions)	Groundwater direction and velocity Groundwater quality Groundwater VOC vertical concentrations gradient
	Diffusion/permeability of VOCs in vadose zone (tracer tests)	Transport of VOCs in basalt Transport of VOCs in sedimentary interbeds
	Continuous sampling through interbeds (vapor, physical properties, transportation properties)	Vertical and horizontal extent of VOCs Preferential paths for transport of VOCs Transport of VOCs in sedimentary interbeds
	Geophysical logging	Vertical and horizontal extent of VOCs Thickness of aquifer Preferential paths for transport of VOCs Transport of VOCs in basalt Transport of VOCs in sedimentary interbeds

Pathway	Field activity	Data gap
	Packer tests (in open wells)	Vertical VOC vapor concentrations gradient Vertical and horizontal extent of VOCs
	Shallow well vapor ports	Vertical vapor concentrations gradient Vertical and horizontal extent of VOCs VOC flux to groundwater
	Deep well vapor ports	Vertical VOC vapor concentration gradient Vertical and horizontal extent of VOCs VOC flux to groundwater Transport of VOCs in basalt Transport of VOCs in sedimentary interbeds
	Vapor pressure and temperature in pits/vadose zone	Vertical VOC vapor concentration gradient VOC surface flux Estimate of VOC vapor pressure in pit
Soils		Recent prior soil sampling shows no significant organic contaminants adsorbed onto surface soils at SDA. No data gaps, reference Section 3.